Pfizer Inc.
100 Route 206 North,MS4LLA
Peapack, NJ 07977
Tel: 908-901-8630

January 25, 2019

Ms. Khrystie Vázquez
Project Manager
U.S Environmental Protection Agency
City View Plaza II Building, Suite 7000
#48 RD, 165 Km. 1.2
Guaynabo, PR 00968-8069

RE: RCRA CORRECTIVE MEASURE STUDY – ADDENDUM
FORMER UPJOHN - RCRA CORRECTIVE ACTION
EPA ID # PRD090398074
ARECIBO, PUERTO RICO

Dear Ms. Vázquez:

On behalf of Pfizer Pharmaceuticals LLC (PPLLC), please find attached an addendum to the *Final Corrective Measure Study Summary Report* (CMS) (ERTEC, 2005), prepared by CH2M HILL Engineers Inc. (CH2M) - that proposes to modify the existing target cleanup levels with performance-based closure standards that are protective of human health and the environment, consistent with our February 20, 2018 meeting discussions.

To help address any questions you or your management may have, it would be helpful to schedule a meeting to review the attached CMS addendum.

Sincerely,

William D. Sieske

Pfizer Pharmaceuticals LLC - a subsidiary of Pfizer Inc.

Cc: Rachel Griffiths, USEPA (via email)
Adalberto Bosque, USEPA (via email)
Emil Filc and Russ Bowen CH2M/Jacobs

R E P O R T

Addendum to Final Corrective Measure Study Summary Report Former Pfizer Arecibo, Puerto Rico Facility

Prepared for

Pfizer

January 2019

CH2M HILL, Inc.
9191 South Jamaica Street
Englewood, CO 80112

Contents

Acronyms and Abbreviations

µg/L	micrograms per liter
bgs	below ground surface
CAO	corrective action objective
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CCl4	carbon tetrachloride
CH2M	CH2M HILL Engineers Inc.
CMS	Corrective Measures Study
COC	contaminant of concern
EPA	United States Environmental Protection Agency
IC	institutional control
MCL	maximum contaminant limit
mg/kg	milligram per kilogram
Pfizer	Pfizer Pharmaceuticals LLC
RBC	Risk Based Concentration
RCRA	Resource, Conservation and Recovery Act
ROD	Record of Decision
site	Pfizer Pharmaceutical LLC – Arecibo Site
SVE	soil vapor extraction
UST	underground storage tank
VI	vapor intrusion

SECTION 1

Introduction

CH2M HILL Engineers Inc. (CH2M) is submitting this report, on behalf of Pfizer Pharmaceuticals LLC (Pfizer), as an addendum to the *Final Corrective Measure Study Summary Report* (CMS) (ERTEC, 2005), which was prepared pursuant to the Resource, Conservation and Recovery Act (RCRA) Part B Permit (EPA, 2000). The CMS was approved by the United States Environmental Protection Agency (EPA) as defining the final corrective measure to address impacted soil media (source zone) at the formerly named Pharmacia and Upjohn Caribe, Inc. site currently known as Pfizer Pharmaceutical LLC – Arecibo Site (site). The CMS recommended using the existing soil vapor extraction (SVE) system to treat contaminants of concern (COCs) in soil which included: acetone, carbon tetrachloride (CCl_4), chloroform, and methylene chloride. Target cleanup levels for the four COCs were based on 2005 EPA Risk Based Concentrations (RBCs) for Region III.

After 16 years of SVE operations from wells SVE-1, VMW-1, VMW-2 and VMW-3C, , soil samples were collected in late 2016 to evaluate the performance of the SVE system as prescribed by the *Revised Post-Remedial Sampling Plan* (ERTEC, 2006). As part of the effort, two new SVE wells were installed to address residual contaminants encountered at depth intervals between 100 and 200 feet below ground surface (bgs). These two new SVE wells have been in operation since early December 2016. The original SVE well, SVE-1, began operation in February 2000. The three supplemental SVE wells, VMW-1, VMW-2, and VMW-3C, have been operating since August 2002. Since startup of the two new SVE wells in December 2016, an estimated total of over 5,900 pounds of total COCs was removed. This is in addition to the prior 1,300 pounds of mass removal (ERTEC, 2016).

After reviewing the current soil data (CH2M, 2017a) and discussion with EPA at a meeting held on February 20, 2018, it has become clear that achieving the target cleanup levels (e.g. 0.03 mg/Kg for CCl_4) specified in the Final CMS using the SVE system is not technically feasible within a reasonable period because of the combined nature of the contaminants within the complex site lithology, including tight clays intermixed with weathered limestone. The SVE system has, however, removed a significant amount of COC mass and there are no current complete exposure pathways because of site conditions and in-place institutional controls (ICs).

This addendum proposes to modify the existing target cleanup levels with performance-based closure standards that are protective of human health and the environment by addressing current and potential future exposure pathways. These performance standards are:

1. Removing remaining COCs in soil to the extent necessary to be protective of groundwater (i.e., off-site wells MW-18 and MW-17, near the site margin, remain below maximum contaminant limits [MCLs] or groundwater use is restricted to prevent ingestion of groundwater above MCLs);
2. Achieving groundwater cleanup standards which are addressed in the Record of Decision (ROD; EPA, 1988) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA);
3. Evaluating the potential for vapor intrusion (VI) and controlling this exposure pathway if needed; and
4. Successfully demonstrating through industry-standard mass removal performance monitoring techniques (e.g., decline curve analysis) that the SVE system has removed COCs to the extent practicable or further SVE operation will not significantly improve groundwater quality.

This approach is consistent with the provisions of the Final CMS that allow for evaluation of alternative clean up goals if soil confirmation samples exceed the RBCs. Those provisions are as follows:

1. Continue with SVE operations as currently constructed;
2. Installation of additional extraction wells;
3. Performance of a risk assessment to determine the site-specific cleanup levels; and
4. Evaluation of other soil treatment alternatives.

Two of the four CMS options have been completed including continued SVE operation and installation/operation of two additional SVE wells. The third option is addressed using an exposure assessment that is proposed to evaluate the VI pathway and assess if engineering controls (e.g. vapor controls) may be required for future construction around the former UST area. Lastly, additional sustainable soil treatment alternatives (e.g. thermally enhanced SVE), as discussed in the latest SVE report (CH2M, 2018), are being evaluated and tested.

Conceptual Site Model and Exposure Pathways

2.1 Site Background

In 1982, approximately 15,300 gallons of a mixture of CCl4 and acetonitrile was found to have leaked from an underground storage tank (UST) at the Upjohn Manufacturing Company Arecibo Facility. Several interim measures were undertaken immediately, which included tank excavation, providing alternate water supply wells to local users, pumping and treating of downgradient impacted groundwater, and installing an SVE system to remove CCl4 from soil beneath the tank farm containing the leaking UST. The original SVE system was operational from 1983 to 1988 in shallow SVE wells in the UST area.

The site was listed on the National Priorities List of Superfund sites in September 1984. In 1987, EPA and Upjohn entered into a CERCLA Administrative Order on Consent to address site groundwater. It was agreed that soil would be addressed through the RCRA program, as described in the Introduction. The 2005 CMS and this CMS addendum pertain to onsite soil impacts and as such, the remainder of this site background discusses activities performed under the RCRA program.

In 1993 through 1995, two phases of a RCRA Facility Investigation were performed. The results indicated that soil contamination was only present at one location (EB-2A-II), corresponding to the former tank farm area, at depths between 140 to 195 feet bgs. An SVE system was installed at this location and began operation in February 2000. In 2005, EPA approved the CMS, which proposed this SVE system as the final remedy for the site and established target cleanup levels for site COCs, as follows: acetone (8.0 milligrams per kilogram [mg/kg]), CCl4 (0.03 mg/kg), chloroform (0.3 mg/kg), and methylene chloride (0.01 mg/kg).

The CMS also proposed shutdown criteria for the SVE system and post remedial sampling to determine the effectiveness of the cleanup. In 2016, -the prescribed sampling was implemented to assess the magnitude and extent of the remaining source. The sampling consisted of installing four borings near the EB-2A-II boring location. Soil COC concentrations were found to be above target cleanup levels at two soil boring locations at depths ranging from 100 to 201 feet bgs. The highest concentrations for each analyte were 11 mg/kg acetone, 17,000 mg/kg CCl4, 39 mg/kg chloroform, and 5.2 mg/kg methylene chloride. Elevated concentrations were generally found within low permeability silts and clays. Two additional SVE wells (SVE-2 and SVE-3) and one vapor monitoring well (VMW-4) were installed to treat and monitor the most highly impacted zones (CH2M, 2017a).

The SVE system was restarted with the two new vapor extraction wells in operation in December 2016. The new wells along with operational improvements initially provided a greater than 10 times increase in mass removal rates (CH2M, 2017b). However, rates have tapered off with each operational period and will likely reach asymptotic levels over the next few operational cycles (CH2M, 2018).

Figure 2-1 shows the general site location along with key features.

2.2 Conceptual Site Model

The site geology generally consists of approximately a 5- to 30-foot thick base layer of colluvium/saprolite (highly weathered limestone) intermixed with layers of lean clay, sandy clay, and silt, which is underlain by a layer of decomposed limestone. However, the former tank farm was located within a localized relict sinkhole, approximately 30 to 40 feet in diameter. The relict sinkhole is approximately 215 feet deep and soil-filled (with some voids). . The composition of stratigraphic layers within the sinkhole are highly variable from location to location and contain several voids, as illustrated on Figure 2-2. As noted in Section 2.1, sampling results from 2016 indicated that elevated concentrations of site COCs are still present at depth within the low permeability silts and thick clays present within the sinkhole. Soil COC concentrations were found to be above target cleanup levels at two soil boring locations at depths ranging from 100 to 201 feet bgs. The site stratigraphy creates a complex contaminant fate-and-transport regime inclusive of large depths, preferential migration pathways (for example, voids), and interbedded with impermeable zones (for example, lean clay). The net effect is remediation impracticability because of costly drilling and limitations to practicably extract the COCs due to low permeability soils. The entrapment of COCs within the low permeability silts and clays limits the ability of the SVE system or most in situ remediation technologies to extract sufficient mass to achieve target cleanup levels in a reasonable period. In turn however, the low-permeability soils that entrap COCs in the relict sinkhole also limit the flux of COCs to groundwater, which is approximately 300 ft bgs.

The shallowest aquifers below the site are the Aymamon and Aguada aquifers, which are approximately 1,800 feet thick with a water table located at approximately 300 feet bgs. Groundwater generally flows to the north-northeast toward the Atlantic Ocean, located approximately 3.7 miles from the site. During the last decade of groundwater monitoring (2007 to 2017), CCl4 was detected at concentrations above the respective MCL. These detections have been limited to a small area in the immediate vicinity of the groundwater extraction wells, specifically, the two extraction wells (UE-1 and UE-2) and two proximal monitoring wells (MW-301B and MW-302).

In September 2017, Hurricane Maria swept through Puerto Rico destroying the water treatment (aeration) system and electrical infrastructure which caused and a loss of power to the site. The SVE system was shut down for a 7-month period and the groundwater extraction system was shut down for a 1-year period. During this time, a CCl4 concentration of 5.8 micrograms per liter (µg/L) was detected in offsite downgradient well MW-18 slightly above the MCL of 5 µg/L. Downgradient well, MW-17, also saw a slight increase to 4.3 µg/L. CCl4 concentrations at MW-1 (located between the source area with the SVE system and the extraction wells) remained stable and ranged from non-detect to 0.68 µg/L, which is consistent with results before the shutdown. This is notable because MW-1 had the highest recorded CCl4 concentration (160 µg/L) during the 20-year period of regular groundwater monitoring (1998 to 2018). Thus, it is likely that the increased concentrations at downgradient wells resulted from desorption of residual mass surrounding the extraction wells rather than downgradient migration from the soil source area. As evidenced by the stable concentration in MW-1 throughout the period, migration of COCs from source area soil to groundwater is very limited.

Figure 2-3 provides a graphical three-dimensional representation of the conceptual site model.

2.3 Current and Potential Future Exposure Pathways

There are currently no complete exposure pathways for COCs in groundwater at the site. A deed restriction is in place prohibiting onsite shallow groundwater use at the site and there are no current known groundwater users of the shallow aquifer near the site. The closest shallow water supply well (Garrachales #3) was located approximately 3 kilometers to the north-northwest and was shut down in 1995. As noted in Section 2.3, groundwater concentrations above MCLs did not extend offsite until an extended shutdown of the groundwater extraction system occurred following Hurricane Maria. Even then, groundwater concentrations above MCLs were limited to a small area just downgradient (to the north) of the site. Regardless, there is a potential for future exposure if offsite groundwater concentrations were to remain above MCLs and a potable water well were installed in these areas. This risk can be controlled by either reducing offsite concentrations below MCLs or by working with offsite landowners to place a deed restriction on the downgradient property/properties affected by the plume.

There are currently no complete exposure pathways for COCs in soil at the site because elevated concentrations are greater than 10 feet deep (which is the depth typically used for worker direct contact exposure scenarios) and below any potential future excavations. Currently, the SVE system is used to extract soil vapor from the affected zone. There is a potential that once SVE operations are discontinued, a buildup of soil vapor near the surface could lead to VI into onsite buildings. This potentially complete pathway requires further evaluation and could be mitigated using engineering or institutional controls, if needed.

Table 2-1 summarizes the various exposure pathways and their current and future status.

Table 2-1. Current and Potential Future Risk Pathways

	Exposure Scenarios		
Environmental Media	**Onsite Worker**	**Offsite Worker/Residential**	**Ecological Receptors**
Groundwater	Prevent ingestion of CCl4 above 5 µg/L (MCL). **Status: Complete, groundwater restriction in place.**	*Prevent ingestion of CCl4 above 5 µg/L (MCL).* ***Status: No current receptors. Potential future receptors to be addressed by attainment of MCL or groundwater restrictions in offsite areas.***	Not applicable because of groundwater depth and lack of surface water discharge.
Soil	Prevent direct exposure to COCs for onsite workers. **Status: No complete pathway because contaminants are greater than 10 feet bgs.**	Not applicable because of no known offsite soil impacts.	Not applicable because of depth of contaminants.
Surface Water	Not applicable because of no known discharge of contaminants to surface water.	Not applicable because of no known discharge of contaminants to surface water.	Not applicable because of no known discharge of contaminants to surface water.
Air (Indoor)	Prevent exposure to COCs in onsite buildings. **Status: Vapors currently being addressed with SVE. Future exposure without SVE is unknown.**	Not applicable because of depth to impacted groundwater.	Not applicable.

SECTION 3

Proposed Remediation Goals

As noted in Section 1, the Final CMS proposed target cleanup levels which are based on EPA Region III RBCs for protection of groundwater. Because of the site-specific conditions (presented in Section 2) the levels are likely not achievable in a reasonable period. Pfizer proposes the following corrective action objectives (CAOs) that are protective of human health and the environment by addressing all current and reasonably expected future uses and exposures. These proposed CAOs will replace the current target cleanup levels for soil.

The primary CAOs are as follows:

- Remove COCs in soil to prevent current and future exposure to off-site groundwater above MCLs for potable uses.
- Prevent current and future onsite exposure to soil vapor concentrations greater than applicable soil vapor-to-indoor air vapor intrusion screening levels, assuming a target risk for carcinogens of 10^{-5} or a target hazard quotient for non-carcinogens of 1.
- Operate the SVE to remove COCs to the extent practicable or to the point when further SVE operation will not significantly improve groundwater quality.

The following subsections describe how Pfizer intends to achieve each of the CAOs and the proposed plans for SVE shutdown.

3.1 Current and Future Groundwater Exposures

As noted in Section 2.2, evidence indicates that leaching from source area soil to groundwater is limited and does not appear to result in groundwater concentrations above MCLs. As the SVE system has been effective at removing contaminant mass from more permeable zones, residual mass remains trapped in low permeability layers, which both limits its ability to be extracted with SVE as well as its mass flux into the groundwater. Groundwater remediation is currently regulated under the CERCLA program.

Pfizer proposes that soil cleanup be tied directly to the milestone of achieving groundwater closure (either via cleanup levels or technical impracticability waiver) under CERCLA as documented in the ROD (EPA, 1988) and *Explanation of Significant Differences* (EPA, 1989) for the site. Completion of this milestone will serve as direct evidence that soil contamination has been addressed to the extent necessary to be protective of groundwater. The established cleanup level in groundwater for CCl4 is currently based on the MCL of 5 µg/L; however, the ROD allows that “it is not known whether contaminant levels in the aquifer can be reduced to the MCL” and that a “waiver from the MCL for reasons of technical impracticability” may be considered if warranted by evaluation of practicability and cost-effectiveness. Such a waiver, if implemented, would include ICs to prevent the potential for human exposure to groundwater concentrations above MCLs.

3.2 Current and Future Soil Vapor Exposures

The current operation of the SVE system is effectively capturing and venting subsurface vapors. Sampling will be performed to evaluate the potential for VI exposure pathways at the site without operation of the SVE system. A workplan for conducting this evaluation is presented as Attachment 1 of this document. If soil vapor concentrations exceed the levels described in the CAOs, mitigation measures or additional sampling will be proposed.

3.3 Soil Vapor Extraction Shutdown

Pfizer proposes continuing operation of the SVE system for an additional 2-year period (2019 and 2020) or until MCLs are achieved in groundwater. During this time, the SVE system will continue to be operated on an approximately 2-month-on and 2-month-off cycle, or as deemed appropriate to maximize mass removal. Additionally, a pilot test will be conducted starting in early 2019 to attempt to increase COC mass removal rates using hot air injection to promote volatilization of residual COC mass in clay-rich low-permeability soils.

Following the conclusion of the 2-year period, the SVE system and groundwater extraction systems will be shut down for a 1-year period (similar to that conducted following Hurricane Maria) to evaluate the changes in groundwater concentrations. During this shutdown period, the groundwater would be monitored in the same manner as was done following Hurricane Maria (i.e. monthly for the first three months and then quarterly).

The results will be compared to the results of the 1-year post-Hurricane Maria shutdown in 2017/2018. The intent of this evaluation will be to demonstrate what benefits, if any, the additional 2 years of SVE operation had on reduction in groundwater concentrations.

Specifically, if the COC rebound is markedly different (that is, slower or of lower magnitude), then it may be concluded that additional SVE operation was beneficial and additional SVE operation would likely be proposed. To the contrary, if rebound is similar to post-Hurricane Maria, then it may be concluded that additional SVE operation was not beneficial and discontinuation of the SVE operation would be proposed. This is because this occurrence would demonstrate that there is not a connection between the soil source and groundwater concentrations.

During this period, Pfizer will prepare annual reports documenting the effectiveness of the SVE.

SECTION 4

Conclusion

The existing SVE system has been successful in removing significant quantities of COCs since its operation started in 2000. However, verification sampling has shown that elevated concentrations of residual COCs persist, trapped in low permeability soil lenses (clays and silts). Based on the evidence provided herein, and despite the additional remedial measures that have been implemented, it is apparent that the RBC-based target cleanup levels as proposed in the CMS cannot be achieved in a timely or cost-effective manner.

There are no current exposure pathways. The remaining mass in the source area soil is not a significant threat to groundwater because leaching of COCs from soil to groundwater is rate-limited based on current groundwater concentrations and historical trends. Additionally, the depth of the COCs do not present an exposure pathway via direct contact. The presence of soil vapor nearer to the ground surface (although unlikely) may result in a potential exposure pathway for indoor air and a VI assessment is proposed herein to further evaluate it. Regardless, potential future exposure pathways, if they are present, can be controlled using means other than the SVE system.

The revised cleanup targets, proposed as CAOs in this report, are protective of human health and the environment by addressing all potentially complete exposure pathways (offsite groundwater and onsite VI). The proposed additional 2-year period of SVE operation is expected to remove a significant amount of residual COC mass in source area soil. Following the 1-year shutdown and rebound monitoring period, Pfizer will evaluate whether the CAOs have been achieved, and if they have will petition the EPA to permanently shut down the SVE system and close the site.

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References

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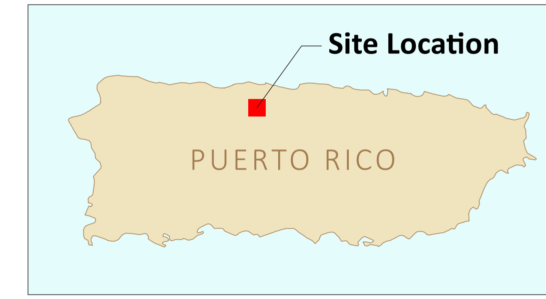
Figures

Aerial 2017 Google Earth. Image © 2017 Digital Globe.



LEGEND

Property boundary

Monitoring well

Extraction well

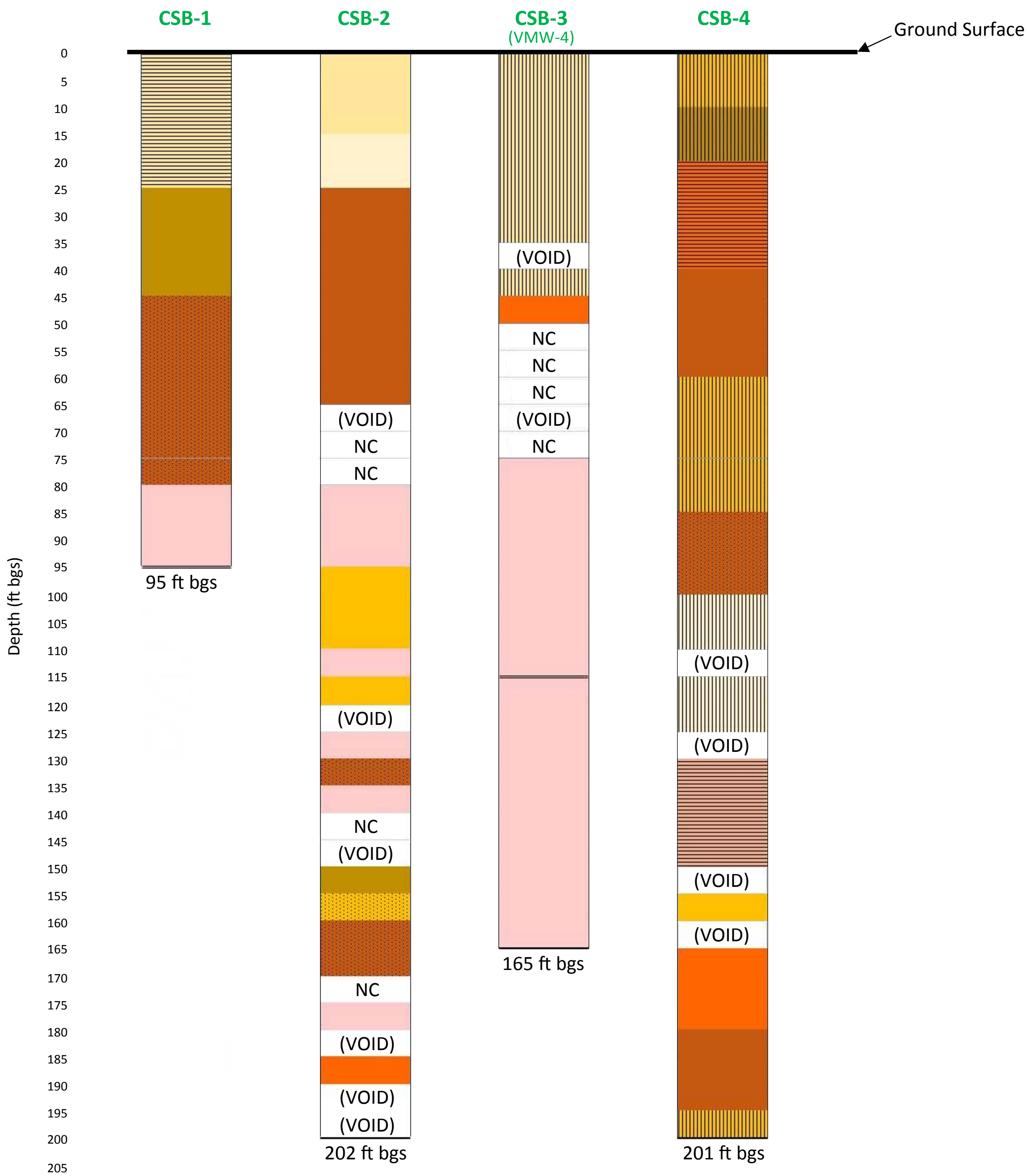
NOTES

1. Well locations from Ertech, 2015.
2. All locations approximate.

FIGURE 2-1
Facility Map
Addendum to Final Corrective
Measure Study Summary Report
Pfizer Pharmaceuticals LLC – Arecibo Site

ch2m

PR1011171240GNV_r2



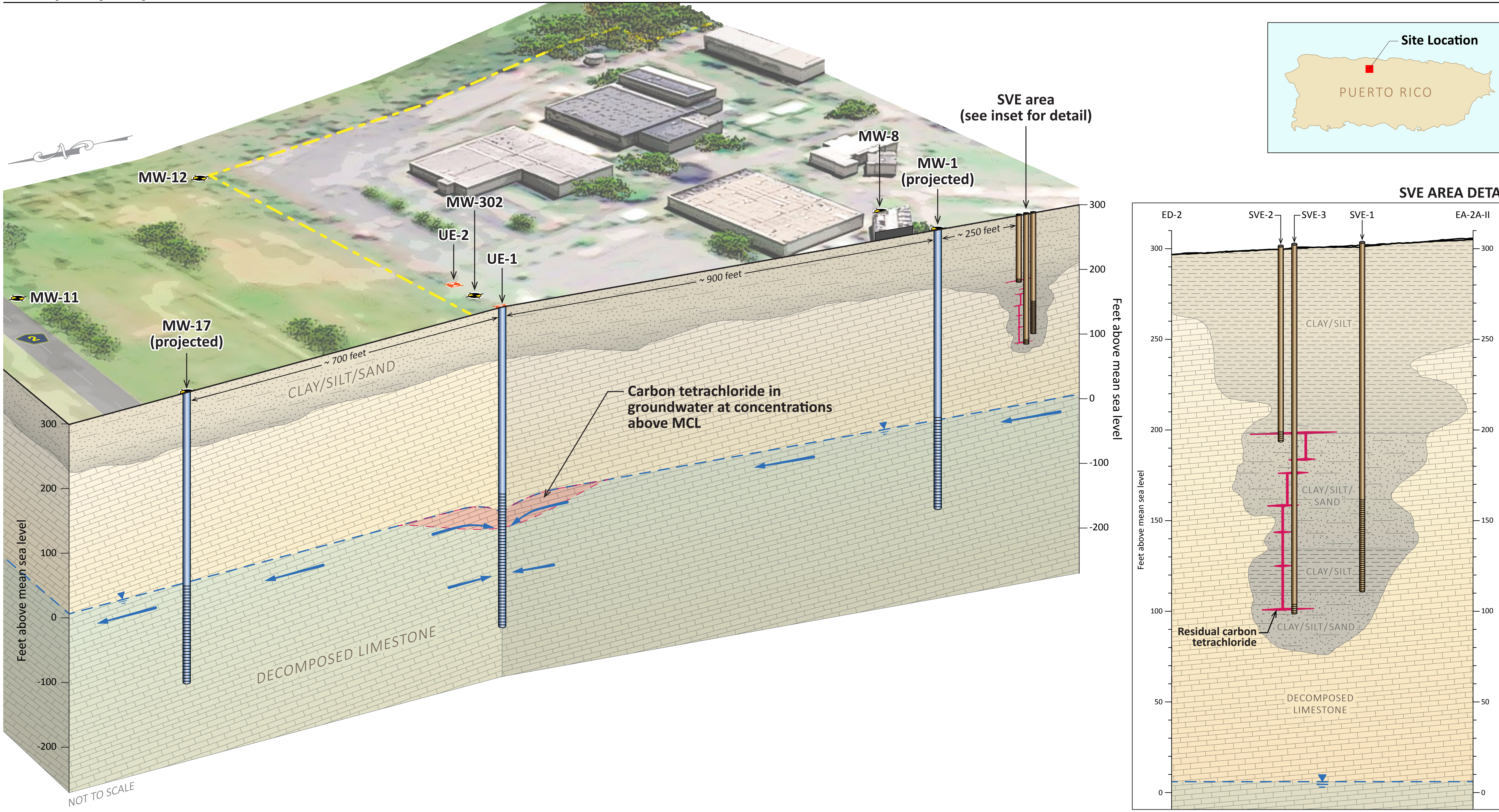
LEGEND

	With lean clay
	With silt
	With sand
	Lean clay
	Lean clay & silt
	Sandy clay
	Silt
	Sandy silt
	Silty sand
	Sand
	Decomposing limestone
NC	No cuttings

NOTES

1. Based on 2016 soil boring investigation.
2. All locations are within ~25 feet of each other.
1. ft bgs = feet below ground surface.

FIGURE 2-2
Lithology of Source Area
Addendum to Final Corrective Measure Study Summary Report
Pfizer Pharmaceuticals LLC – Arecibo Site



LEGEND

- Property boundary
- Water table
- Groundwater flow direction
- Groundwater monitoring well
- Groundwater extraction well
- Soil vapor extraction (SVE) well
- Carbon tetrachloride in groundwater at concentrations above MCL

NOTE: MCL for carbon tetrachloride in groundwater = 5 µg/L.

FIGURE 2-3
3D Conceptual Site Model
Addendum to Final Corrective Measure Study Summary Report
Pfizer Pharmaceuticals LLC – Arecibo Site

PR1011171240GNV

Attachment 1
Soil Vapor Assessment Workplan

Attachment 1
Soil Vapor Investigation Work Plan

1 Introduction

1.1 Purpose and Objectives

This work plan describes the approach and procedures for soil vapor investigation activities at the formerly named Pharmacia and Upjohn Caribe, Inc. site currently known as Pfizer Pharmaceutical LLC – Arecibo Site (site).

The objective of the investigation is to evaluate the potential for current and future vapor intrusion (VI) exposure pathways at the site. Additionally, information gathered during this investigation will be used to fill data gaps in the current conceptual site model (CSM). Implementation of this work plan will provide the data necessary to evaluate the presence of site-related volatile organic compound (VOC) contamination in soil vapor near the source area.

2 Investigation Approach

Soil vapor sampling will be performed at the site to evaluate the presence of site-related VOC contamination in soil vapor. The soil vapor sampling results will be compared to the United States Environmental Protection Agency (EPA) VI screening levels (VISLs; EPA, 2018) for soil vapor in a commercial land use setting to evaluate the potential for current and future VI exposure pathways at the site, which will fill the data gaps in the CSM. The VISLs are EPA's standard screening levels for evaluation of the VI pathway.

The proposed soil vapor sampling locations were selected to bound the VOC source area which includes the former underground storage tank farm and the sinkhole where the released product has settled (Figure 1). There is currently one building within 100 feet of the source area. That building is being used as the soil vapor extraction (SVE) system control room. The control room is not regularly occupied, with a worker being present in the building for less than 1 hour per month. The remainder of the buildings within 100 feet of the source area have been demolished and only foundations remain.

Soil vapor samples will be collected at a total of 17 locations as shown in Figure 1: eleven (11) shallow soil vapor samples and six (6) subslab soil vapor samples from foundations of demolished buildings.

Exterior soil vapor probes will be installed and sampled at the following locations: One exterior soil vapor sample location is proposed at the center of the source area. Eight exterior soil vapor sample locations are proposed around the source area. Two exterior soil vapor sample location are proposed next to existing buildings which are currently being used for storage: one northeast and one southwest of the source area, to assess the potential for VI at these buildings.

Subslab soil vapor samples will be collected at the following locations: Three subslab soil vapor sample locations are proposed within 100 feet of the source area: one in the SVE control room and two below the foundations of demolished buildings. Three additional subslab soil vapor sample locations are proposed below the foundations of demolished buildings surrounding the source area at a distance greater than 100 feet to provide additional sampling locations for delineation purposes.

The SVE system will be turned off for at least 60 days before soil vapor sampling so that the subsurface has sufficient time to equilibrate and the sampling conditions are representative of future site conditions when the SVE system is no longer operating. One round of soil vapor sampling will be performed as the depth to impacted groundwater (approx. 300 feet below ground surface) and residual soil source (100-200 feet below ground surface) likely limits temporal variability.

The target analyte list is VOCs that were previously detected in soil and/or groundwater within 100 feet of the source area (Table 1).

3 Investigation Activities

3.1 Utility Locate

Before the start of intrusive work at the site, utility-locating activities will be performed in accordance with the CH2M Field Operating Procedure (FOP) Utility Clearance for Intrusive Operations (Appendix A). The purpose of the utility locate will be to ensure the safety of the crew performing intrusive work, and to protect against accidental property loss from damaged utilities.

A utility-locate ticket will be opened through Puerto Rico's one-call public utility-locating service to have the areas surrounding the 16 proposed drilling locations marked for buried active utilities. A third-party utility locator will also survey the site using ground-penetrating radar to identify possible abandoned utility lines and other potential subsurface obstructions. After completion of the public clearance process, the private utility-locating subcontractor will clear a 10-foot radius around each proposed drilling location as described in FOP #1. Additionally, the site will be notified before intrusive subsurface activities, and a site representative will consult available utility drawings.

If utilities or other subsurface obstructions are identified during the utility locating, the proposed sampling location(s) will be adjusted. Adjustments will be noted in the field.

3.2 Soil Vapor Sampling Activities

Eleven semi-permanent exterior soil vapor probes will be installed and sampled to evaluate shallow (that is, 5 feet below ground surface [bgs]) soil vapor VOC concentrations. The proposed exterior soil vapor sample locations are shown on Figure 1.

The soil vapor probe installation will follow the CH2M FOP for Installation and Abandonment of Permanent and Semi-Permanent Exterior Soil Vapor Probes (Appendix A). The soil vapor probe installation will be based on equipment and subcontractor availability but will including the use of one or more of the following techniques: direct-push, hand auger, and AMS, Inc. hand tooling. In summary:

- Each soil vapor probe will be constructed with an expendable implant anchor and a soil vapor sampling implant (that is, probe screen) made of stainless-steel wire-mesh screen with a 0.5-inch outer-diameter. The screen will be attached to Teflon tubing that will extend to the ground surface where it will terminate in a compression fitting (that is, Swagelok). The probe screen length will be dictated by the installation method, but it will range from 1 to 6 inches.
- Soil vapor probes will be advanced to a final depth that allows the top of the screened interval to be 5 feet bgs.
- Collection of soil cores will not be necessary because soil cores have been collected previously in the area and the sampling points will be well above the groundwater table.
- Soil vapor probes will be installed in a manner that creates a leak-free seal between the sampling point and the above-ground atmosphere. Sand will be used to create a 1-foot high sand pack around

the screen followed by enough dry granular bentonite to create a 6-inch high interval. The remainder of the hole with be filled with granular bentonite hydrated in lifts.

- The soil vapor probes will be covered with a temporary polyvinyl chloride (PVC) cap so that they can be abandoned easily after the sampling is completed. .
- The exterior soil vapor probes will be given at least 48 hours to equilibrate after installation is completed before sampling.

Exterior soil vapor sampling activities will be conducted in accordance with CH2Ms FOP Soil Vapor Sampling from Exterior Soil Vapor Probes (Appendix A). In summary:

- Each exterior soil vapor probe will be helium leak checked, and three dead volumes of soil vapor will be purged before sampling. The dead volume will include the probe screen, sand pack, and tubing.
  - Leak checking will be performed to confirm that the soil vapor probes were installed correctly so that ambient air will not be drawn into the sample, which would potentially dilute VOC concentrations. The leak-check procedure consists of placing a shroud around the soil vapor probe, flooding the shroud with helium gas, and measuring the helium concentration in the purged soil vapor.
  - The helium-leak check results are interpreted by comparing the helium concentration present in the purged soil vapor to those present in the shroud during purging. If the purged soil vapor contains helium at a concentration greater than 5 percent of the concentration present in the shroud, then the helium-leak check indicates that a leak exists, either in the sampling train or within the soil vapor probe, allowing helium (and ambient air) to be drawn into the probe screen. Attempts will be made to repair leaks, and if they are not successful then the probe will not be sampled.
  - The soil vapor probes will be purged with a sampling manifold (consisting of stainless-steel Swagelok gas-tight valves and fittings) and a vacuum air pump. Soil vapor will be purged at 200 milliliters per minute (mL/min) into a Tedlar bag. The Tedlar bags will screened using a MiniRAE photoionization detector (PID) for total VOCs and a MGD-2002 helium detector for helium concentrations.
- Exterior soil vapor samples will be collected at a sampling rate of 200 mL/min in 1-liter evacuated canisters (approximately a 5-minute sampling duration) that are batch certified clean. The soil vapor samples will be submitted to the subcontracted laboratory for analysis of VOCs by EPA Method TO-15.

3.3 Subslab Soil Vapor Sampling Activities

Six (6) subslab soil vapor probes will be installed and sampled to evaluate shallow soil vapor VOC concentrations. The proposed subslab soil vapor sample locations are shown on Figure 1.

Subslab soil vapor probe installation will be conducted in accordance with CH2Ms FOP Installation and Abandonment of Vapor Pins as Subslab Soil Vapor Probes (Appendix A). In summary:

- The subslab soil vapor probes will be installed in competent, intact concrete slabs of former buildings. The probes will be placed at least 5 feet away from the slab edges, any cracks, or penetrations in the slab to avoid short-circuiting of ambient air.
- A hole will be drilled through the concrete slab with a rotary hammer drill, and a Cox-Colvin & Associates, Inc. Vapor Pin will be inserted into the hole.
- The subslab soil vapor probes will be given at least 2 hours to equilibrate after installation is completed prior to sampling.

Subslab soil vapor sampling will be conducted in accordance with CH2Ms FOP Sub-Slab Soil Vapor Sampling from Vapor Pins (Appendix A). In summary:

- Subslab soil vapor samples will be collected at a sampling rate of 200 mL/min in 1-liter evacuated canisters (approximately a 5-minute sampling duration) that are batch-certified clean. The soil vapor samples will be submitted to the subcontracted laboratory for analysis of VOCs by EPA Method TO-15. QA/QC soil vapor samples for laboratory analysis will be collected as detailed in Worksheet #20.
- Each subslab soil vapor probe will be leak checked using the water dam method, and one liter of soil vapor will be purged prior to sampling.
  - Leak checking is performed to confirm that the subslab soil vapor probes were installed correctly so that ambient air will not be drawn into the sample, which would potentially dilute VOC concentrations. The leak-check procedure consists of placing a dam around the soil vapor probe, filling it with water, and watching for bubbles during purging which would indicate a leak. Attempts will be made to repair leaks, and if they are not successful then the probe will not be sampled.
  - The soil vapor probes will be purged with a sampling manifold (consisting of stainless-steel Swagelok gas-tight valves and fittings) and a vacuum air pump. Soil vapor will be purged at 200 mL/min into a Tedlar bag. The Tedlar bags will screened using a MiniRAE PID for total VOCs.
- Subslab soil vapor samples will be collected at a sampling rate of 200 mL/min in 1-liter evacuated canisters (approximately a 5-minute sampling duration) that are batch-certified clean. The soil vapor samples will be submitted to the subcontracted laboratory for analysis of VOCs by EPA Method TO-15.

3.4 Quality Assurance and Quality Control Sampling

Canisters supplied by the laboratory must follow the performance criteria and quality assurance prescribed in EPA Method TO-14/15 for canister cleaning, certification of cleanliness, and leak checking.

Flow controllers supplied by the laboratory must follow the performance criteria and quality assurance prescribed in EPA Method TO-14/15 for flow controller cleaning and adjustment.

Field duplicates will be collected to determine the precision of the field team's sampling procedures. Field duplicates will be collected and analyzed at a frequency of 1 duplicate for every 10 samples. During collection of field duplicates for soil vapor sampling, two canisters will be connected with a T-connector provided by the laboratory to allow for collection of the parent and duplicate sample at the same time. Field duplicate soil vapor samples will be collected using one flow regulator so that the parent and duplicate sample collect at the same flow rate.

Data will be reviewed and validated to confirm they meet established quality parameters.

3.5 Laboratory Analysis

The soil vapor samples will be submitted to an accredited laboratory for analysis of the target analytes listed in Table 1. The samples will be analyzed using EPA Method TO-15 SCAN.

3.6 Decontamination Procedures

Drilling equipment, downhole tooling, and sampling equipment will be decontaminated between sample locations using a laboratory-grade detergent diluted to the manufacturer's suggested ratio. New disposable tubing will be used for each sample.

3.7 Sampling Location Surveying

Northing and easting coordinates will be collected using a global positioning system (GPS) unit at each soil vapor sampling locations. The geospatial data will be used to augment the CSM.

3.8 Investigation-derived Waste Management

Investigation-derived waste generated during the soil vapor investigation will likely consist of decontamination water, tubing, personal protective equipment (PPE), decontamination materials (such as paper towels), and disposable sample supplies. Waste materials will be segregated by media (water, PPE, etc.), and the placed in U.S. Department of Transportation–approved 55-gallon drums. The drums will be labeled and staged at the site pending pickup. PPE will be disposed of in a designated site dumpster.

Miscellaneous wastes (soil vapor tubing, Tedlar bags, etc.) that did not come in contact with potentially contaminated soils or liquids will be disposed of as general solid waste in municipal trash receptacles.

3.9 Sample Identification

CH2M has devised a sample numbering system that will be used to identify each sample, including duplicates and blanks. The method of sample identification (ID) used depends on the type of sample collected. Field data will be recorded in bound field logbooks or recorded on data sheets along with sample identity information. Labels for samples sent to a laboratory for analysis will be written in indelible ink. The following information is typically included on the sample label:

- Site name or identifier
- Sample identification (ID)
- Date and time of sample collection
- Sample matrix or matrix identifier (SV=exterior soil vapor, SS=subslab)
- Type of analysis to be conducted

Each analytical sample will be assigned a unique ID as described below.

Exterior soil vapor is as follows: **PAF-SV01-XXXX-MMDDYY**

Subslab is as follows: PAF-SS01-MMDDYY

Where:

PAF = Pfizer Arecibo Facility
SS = subslab
SV = exterior soil vapor
XXXX = soil vapor probe screen depth (12-inch screen, set at **XX** to **XX** feet bgs)
MMDDYY = Month, day and year sample was collected
FD = Field duplicate

Examples:

- Duplicates will be blind. The duplicates will be numbered consecutively if more than one duplicate is collected in a day. The first field duplicate collected on November 1, 2018 would be **PAF-110118-FD01.**
- A soil vapor sample collected on November 5, 2018 at location 01 with screen interval from 5 to 6 feet would be **PAF-SV01-0506-110518.**

The sample IDs will be tracked electronically from collection through laboratory analysis and into the final reports. The sample ID will be checked to make sure it matches what is entered on the chain-of-custody form.

3.10 Field Documentation

Field team members will document soil vapor investigation information and data in the field logbook. The field logbook will have consecutively numbered and bound pages that cannot be removed. The logbook cover will indicate the following:

- Project name
- Project number
- Project manager's name
- Sequential logbook number
- Activity or task
- Project start date
- Project end date

Logbook entries will be made continuously throughout the day. Entries will be recorded in ink, with incorrect entries stricken with a single line and initialed. The date and time will be recorded at the beginning of each entry. Entries will include, but are not limited to, summaries of daily activities, subcontractor management issues, names of visitors, sample collection information, health and safety briefing topics, and out of scope activities.

Data collection forms will also be used to record investigation information and data. The data collection forms will be used in conjunction with the field logbook. All documents generated during the field effort are controlled documents that become part of the project file.

3.11 Data Validation

Data collected as part of this work plan will be consistent with the Quality Assurance Project Plan and will be validated (to Level 3) by CH2M. Validation of laboratory data packages will include an assessment of compliance with method guidelines, an evaluation of holding times, blank contamination, calibration requirements (initial and continuing), surrogate spike recovery, matrix spike/matrix spike duplicate recoveries, instrument performance, and compound ID and quantitation, as applicable.

The following steps are included as part of the data validation process:

- Evaluate the completeness of the data package.
- Verify field chain-of-custody forms were completed and that samples were handled properly.
- Verify holding times were met. Samples with holding time exceedances will be documented and flagged accordingly.
- Verify that parameters were analyzed according to methods specified.
- Review quality assurance (QA) and quality control (QC) data. Work with the QA coordinator and/or the laboratory QA manager to resolve QA/QC issues.

4 Data Evaluation and Reporting

A report will be prepared to document the methods and results of the soil vapor investigation and will be submitted to EPA 90 days after completion of field activities.

This report will include the following:

- Description of the soil vapor sampling procedures including any deviations from this work plan
- Figure showing the sampling locations based on the GPS data
- Table of the validated soil vapor sampling results compared to the EPA soil vapor VISLs, based on a target cancer risk (TCR) of $1x10^{-5}$ and a target hazard quotient (THQ) of 1 (whichever is lower) (Table 1). The most recent EPA VISLs available at the time of the evaluation will be used. The analytical data will be compared to commercial VISLs because the site is deed restricted to commercial/industrial use.
- Evaluation of cumulative risk associated with potential commercial worker indoor air exposures to multiple detected chemicals if site-related VOCs are detected. Cumulative risk will be calculated using EPA's VISL Calculator (EPA, 2018), and evaluated against EPA's acceptable risk range of 10^{-4} to 10^{-6} and target organ-specific Hazard Index threshold of 1.
- Evaluation of the potential for current and future VI exposure pathways based on the soil vapor sampling results and other relevant lines of evidence (i.e., soil and groundwater data from previous investigations, soil type, ground covering, condition, and use of the buildings) as necessary.
- Data validation report
- Copy of the final laboratory data package
- Recommendations for further investigation or mitigation of the VI pathway, if necessary

The soil vapor investigation results will also be incorporated into the CSM and will be used to support the overall site characterization and remedial action planning.

Vapor Intrusion Uncertainty Evaluation

If there are exceedances of VISLs, an uncertainty evaluation will be performed to assess uncertainty associated with the indoor air risk estimates. The most recent version of the Johnson & Ettinger Model Spreadsheet Tool (JEM), Version 6.0 (EPA, 2017) will be used to consider site-specific conditions. The spreadsheet tool implements the steady-state solution to vapor transport (infinite or non-diminishing source and steady-state vapor concentrations) described by Johnson & Ettinger (1991).

A range of site-specific input parameters, such as soil type and building size, will be used in the model to estimate a range of indoor air concentrations. If appropriate, it will be assumed that all buildings are slab-on-grade and site-specific building information will be used for existing buildings (e.g., number of stories, area of building). The depth below grade for the soil vapor samples collected and the average slab thickness observed during subslab sampling may be used as the input value for the foundation thickness parameter. The default value of 0.1 m for the depth below grade to the base of the foundation may be used if it is appropriate to assume that current and future buildings do not have foundations (in other words, buildings are constructed slab-on-grade).

Since the indoor air exchange rates (air changes per hour [ACHs]) of site buildings are unknown, a range of assumptions will be made about ACHs based on literature values for buildings with similar construction. The range of potential building types, air exchange rates, and subsurface conditions, as well as their potential impact on vapor migration and estimated indoor air concentrations, will be discussed. Likewise, the use of subslab soil vapor analytical results from former building foundations and exterior soil vapor to represent site conditions after redevelopment will be discussed.

5 References

U.S. Environmental Protection Agency (EPA). 2018. Vapor Intrusion Screening Level (VISL) Calculator (XLSM), Version 3.5.2. January. http://www.epa.gov/oswer/vaporintrusion/guidance.html.

U.S. Environmental Protection Agency (EPA). 2017. Johnson & Ettinger Spreadsheet Tool, Version 6.0.

Johnson P. and R. Ettinger. 1991. "Heuristic Model for Predicting the Intrusion Rate of Contaminant Vapors into Buildings." *Environmental Science and Technology*. No. 25. pp. 1445-1452.

Figure

Aerial image © 2018 Google Earth.

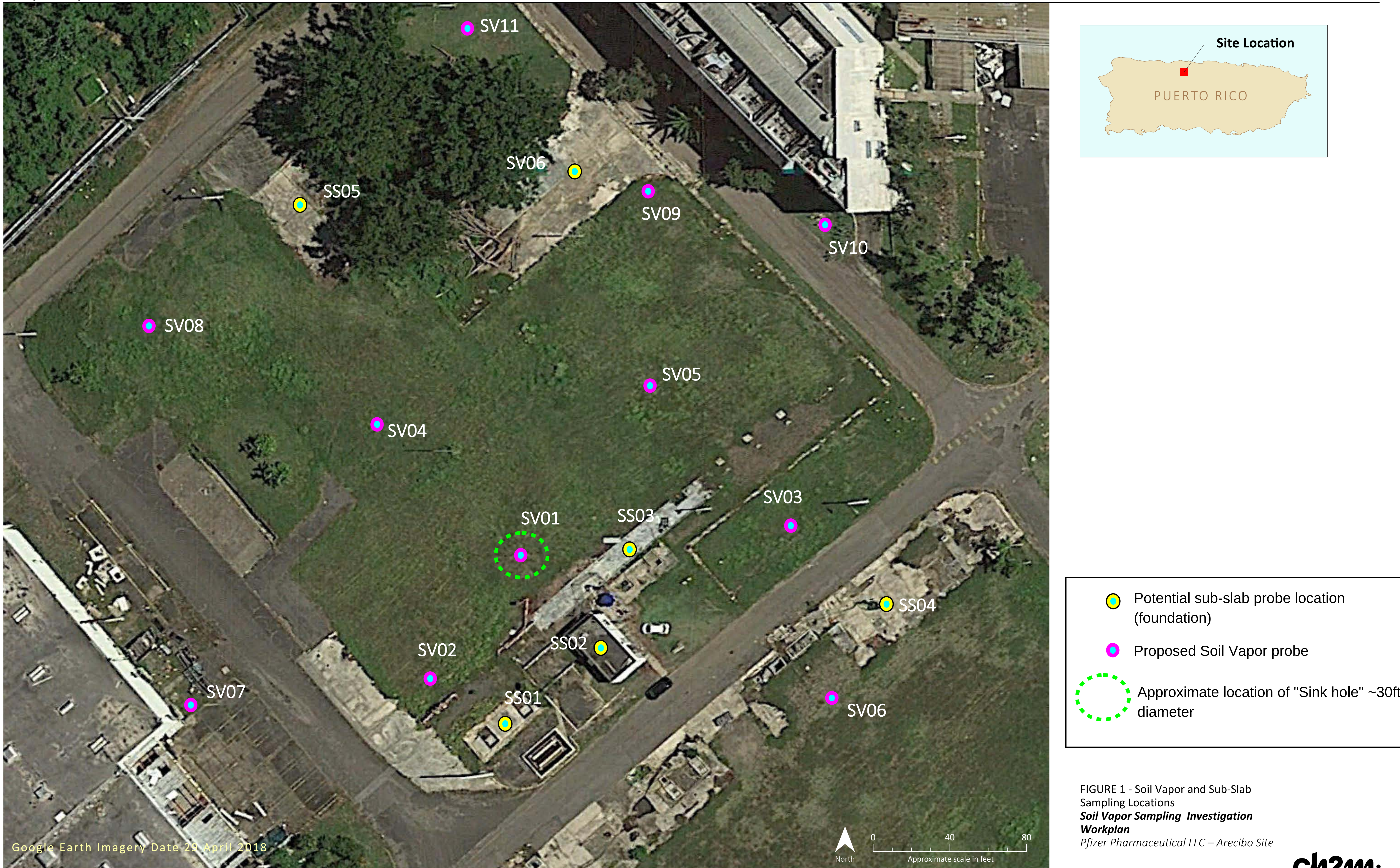


FIGURE 1 - Soil Vapor and Sub-Slab Sampling Locations
Soil Vapor Sampling Investigation Workplan
Pfizer Pharmaceutical LLC – Arecibo Site

ch2m

PR1011171240GNV

Table

Table 1. Soil Vapor Screening Levels

Soil Vapor Investigation Work Plan, Former Pfizer Facility, Arecibo, Puerto Rico

Analyte	CAS Number	EPA Commercial Soil Vapor VISLs[a]
	Units	(µg/m^3)
Acetone	67-64-1	4,510,000
Acetonitrile	75-05-8	8,760
Carbon Tetrachloride	56-23-5	681
Chloroform	67-66-3	178
Methylene chloride	75-09-2	87,600

Notes:

µg/m^3 = micrograms per cubic meter

CAS = Chemical Abstracts Service

EPA = United States Environmental Protection Agency

TCR = target cancer risk

THQ = target hazard quotient

VISL = Vapor Intrusion Screening Level

[a] The EPA commercial indoor air VISLs were developed from the EPA VISL Calculator (EPA, 2018). The VISLs were calculated from the EPA May 2018 Regional Screening Levels based on a TCR = 1 x 10-5, a THQ = 1, and the EPA default soil-gas-to-indoor-air attentuation factor of 0.03.

Appendix A
Field Operating Procedures

Utility Clearance for Intrusive Operations

Purpose

This field operating procedure (FOP) describes the utility mark-out and clearance process to be followed before completing any exterior or interior intrusive subsurface activities.

Scope

This FOP describes the utility mark-out and clearance process to be followed before any exterior or interior intrusive activities. The FOP discusses steps that must occur before mobilizing and during intrusive work.

Equipment and Materials

The private utility locator will supply the necessary equipment and materials.

Procedures and Guidelines

Before Mobilizing to the Field

Before mobilizing to perform exterior intrusive work, the state One Call Center must be called and utility companies must mark out the utility lines. The decision of get a public utility clearance for intrusive work inside of buildings should be made on a project- and site-specific basis. The public utility clearance will only be performed to the private property boundary.

Public Utilities

The state One Call Center **must** be contacted before any exterior intrusive work. The following general information must be provided during the call:

- Your name, company, address, and phone number where you can be reached, and the company doing the digging.
- The name and phone number of the site contact.
- The county and city or county and unincorporated area of the township of the excavation.
- The location of the intrusive work, which may include, but not be limited to, address, cross street, and lot numbers. At least one of the following must be provided: (1) appropriate section and quarter section grid information; (2) sufficient address or descriptive information to allow the establishment or drawing of a dig site polygon; (3) sufficient address, street, and cross-street information to allow for the determination of the appropriate section and quarter section grid(s); or (4) global positioning system coordinates.
- The start date and time of the planned activities.
- If subcontractors are responsible for utility locates, proper documentation must be received from them before the start of intrusive activities and placed in the project folder.

While on the phone with the One Call Center, the following information should be collected and documented in the project files:

1. **Members Notified.** The identity of One Call members notified will be provided to the caller. Retain a copy in the project files and keep it onsite while intrusive work is being performed.
2. **Case Reference Number.** An identification number associated with the call should be retained for future reference, if needed. Retain a copy in the project files and keep it onsite while intrusive work is being performed.

The site safety coordinator should retain a copy in the project records and keep it onsite while intrusive work is being performed.

All public utilities in the area where intrusive work is to be performed should be marked out on the ground by the utility locator using the American Public Works Association (APWA) Uniform Color Code (Attachment 1).

Utility locates are good for 21 calendar days, including the day the call was made. Extended tickets are available and will be extended, and the state One Call Center must be notified if extended tickets are needed.

Private Utility Clearance – Exterior Intrusive Work

Utilities must be cleared by a private utility locator before any exterior intrusive work as follows:

1. Identify the location(s) where intrusive work will occur during a site visit with the private utility locator. The proposed areas where intrusive work will be performed should be premarked before this site visit. It is important to take access issues into consideration while premarking.
2. Verify that the public utility clearance has been completed before beginning the private utility clearance. If it has not been cleared, the state One Call Center must be notified to complete the public utility clearance before the private utility clearance may be performed.
3. Oversee the following tasks performed by the private utility subcontractor:
   - 3.1. Clear a 10-foot by 10-foot area around the area where intrusive work will be performed. Additional area (if possible) to be cleared by the private utility locator is based on the work to be performed.
   - 3.2. Use surface geophysical methods (for example, direct-connect wire tracing, metal detecting, ground penetrating radar, magnetometers, air knife, Acoustic Pipe Locator, RD-7000 locator and Transmitter, Cable Avoidance Tool, and Genny), to identify underground utility lines, pipes, structures, or anomalies.
   - 3.3. Identify, mark out, and differentiate between any underground utilities (for example, electrical, water, gas, sewer, telephone, and cable lines), buried pipes, process lines, structures, and anomalies within the subsurface.
   - 3.4. The cleared area should be marked with white paint or flags, and the proposed intrusive work location should be identified with white paint or flags. Mark with color-coded spray paint and /or pin flags using the same standard color schemes as the state One Call Center shown in Attachment 1 (to indicate electric, gas, water, steam, telephone, TV cable, fiber optic, sewer, and foundation), all identified underground utility lines, structures, and anomalies.
4. Record the name and telephone number of the representative conducting the utility clearances.
5. The utility clearance is applicable for a 30-day period. Any intrusive work conducted after this 30-day period requires a new utility clearance.

Private Utility Clearance – Interior Intrusive Work

Utilities must be cleared by a private utility locator before any interior intrusive work as follows:

1. Identify the location(s) where intrusive work will occur during a site visit with the private utility locator. It is important to take access issues into consideration when the areas to be cleared are designated.
2. Oversee the following tasks performed by the private utility subcontractor:
   - 2.1. Clear a 2-foot by 2-foot area around the area where intrusive work will be performed. Additional area (if possible) to be cleared by the private utility locator is based on the work to be performed.
   - 2.2. Use ground-penetrating radar, electronic utility-locating equipment, and other utility locator technologies that are necessary to identify and differentiate between underground utilities, pipes, structures, or anomalies. A concrete scanner, which is a type of ground-penetrating radar designed for use on concrete slabs, should be used for utility clearance inside of a building.
   - 2.3. Identify, mark out, and differentiate between any underground utilities (for example, electrical, water, gas, sewer, telephone, and cable lines), buried pipes, process lines, structures, anomalies, conduit, rebar, post-tension cables, radiant floor tubing, wire mesh, and other nonconductive targets within or below the concrete slab.
   - 2.4. The cleared area and the proposed drilling location should be marked with chalk, crayons, or tape. If it is not possible to mark utilities, provide a figure that shows the field team exactly where the utilities are located and the extent of the area marked.
3. Record the name and telephone number of the representative conducting the utility clearances.
4. The utility clearance is applicable for a 30-day period. Intrusive work conducted after this 30-day period requires a new utility clearance.

Before and During Intrusive Work

The following should be completed before commencing intrusive work:

1. For exterior intrusive work, verify that all public utility companies have identified the presence of utilities with marking paint or have provided a response back indicating the absence of utilities in the area. To verify what the utility markings on the ground indicate, use the color code in Attachment 1 (for public utilities). If utilities have not been marked or a negative response has not been confirmed, do not perform intrusive work in that area. Contact the state One Call Center and alert them of the situation.

5. For exterior intrusive work being performed by a subcontractor with a drilling rig, review the utility clearance documentation with the drilling subcontractor during the tailgate meeting.
6. For exterior intrusive work, use other methods to identify utilities if there are numerous utility lines around the area and/or lines that cannot be clearly located where intrusive work is to be performed. If possible, hand-digging or hand-augering will be performed down to 5 feet below ground surface (bgs). Another method would involve the use of an air knife to bore 5 feet bgs with the use of high-pressure air that would not damage any utilities encountered.
7. Intrusive work can only be performed in the cleared area. If intrusive work needs to be performed outside of the cleared area, the appropriate utility locator(s) must clear the new location. If the new

area cleared involves private utilities, an addendum to the initial utility clearance signoff sheet should be provided.

8. While performing intrusive work, monitor for signs of an encounter with a utility line. These signs include encountering fill material such as gravel, sand, or other fill material; warning tape; plastic; or metal. If it is believed that a utility was struck, stop work, call the appropriate personnel, and document in the field logbook.
9. If refusal occurs while drilling and it is believed not to be related to a utility, then advancement will be tried up to two more times within the cleared area. If the same refusal is observed, then the location will be abandoned.

Quality Control and Quality Assurance

The field notes and utility-locate drawings will be reviewed by the field quality manager at the end of each work day performed.

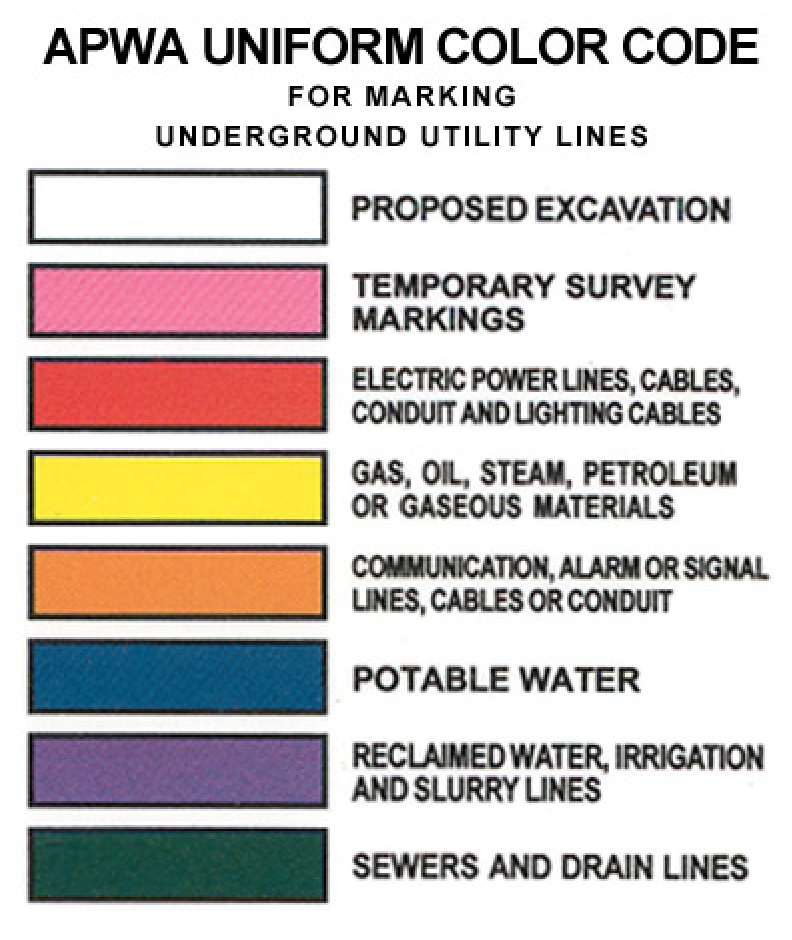
Attachments

APWA Uniform Color Code

References

Not applicable.

Attachment 1



Installation and Abandonment of Permanent and Semi-Permanent Exterior Soil Vapor Probes

Purpose

This field operating procedure (FOP) presents general guidelines for installing and abandoning permanent and semi-permanent exterior soil vapor probes. The number, location, screen depth, and specific installation method for soil vapor probes should be determined on a project-specific basis.

Scope

This is a general description of how to install permanent and semi-permanent exterior soil vapor probes, and how to abandon them when sampling is complete. This FOP covers multiple soil vapor probe installation techniques including direct-push, hand auger, and AMS, Inc. hand tooling. The hand auger and AMS installation methods are only applicable to relatively shallow installation (for example, up to 10 to 15 feet below ground surface [ft bgs] depending on the soil type). Soil vapor probes may be installed with multiple screen depths (nested).

Equipment and Materials

Equipment and materials for the various installation methods are as follows:

- Direct-push tooling and direct-push drill rig, typically supplied by the drilling subcontractor, as follows:
  - Standard single rods are available in multiple sizes (for example, 1-inch, 1.25-inch, 1.5-inch, 1.75-inch, and 2.25-inch outer diameter [OD]).
    - Expendable point holder—sized to mate with the drive rods or fit within a larger outer rod
    - Expendable drive point—steel or aluminum, sized to mate with the expendable point holder
    - Drive cap—sized to mate with the drive rods
  - Dual-tube system (Geoprobe DT21 [2.125-inch OD outer rod], DT22 [2.25-inch OD outer rod], or DT325 [3.25-inch OD outer rod])
    - Cutting shoe—sized to mate with the outer rod
    - Inner rods—1.25-inch OD
    - Drive caps and inner drive cushion—sized to mate with the inner and outer rods
    - Liners with core catchers—sized to mate with the inner rods. The DT21 and DT22 systems use acetate liners, and the DT325 system uses polyvinyl chloride (PVC) liners
    - Optional—tremie pipe for putting sand and bentonite into the rods

- Hand auger tooling:
  - Hand auger—stainless-steel with cross handle and 5-foot extensions
- AMS tooling:
  - Slide hammer or hammer drill for driving the probe (power supply necessary for the hammer drill)
  - AMS drive rods – 0.625-inch OD hollow drive rods
  - Removal jack
  - Dedicated gas vapor probe tip assembly
  - Leather work gloves, vice grips, and a large adjustable wrench

Equipment and materials applicable to all installation methods are as follows:

- Probe screen (that is, vapor implant)—stainless steel. Available in a variety of lengths ranging from 1- to 21-inch. The connection on the screen must be for 0.25-inch OD tubing, and should preferably be Swagelok, but a barbed fitting is also acceptable. The AMS installation tooling requires the use of the AMS 1-inch-long gas vapor tip with plastic umbrella.
- Probe tubing—0.25-inch OD Teflon tubing (may be supplied by the drilling subcontractor)
- Probe cap (to seal the tubing)—Swagelok part number SS-400-C
- Optional for installation directly into augered holes—expendable point to cap the bottom of the probe screen
- Optional for installation directly into augered holes – PVC pipe to keep the borehole open during installation
- Monitoring well screen pack sand to create a permeable layer around the probe screen (this sand pack is the “screened interval” of the probe)
- Recommended - powdered bentonite to create a 6 to 12-inch layer above the sand pack
- Granular bentonite or bentonite slurry to fill the borehole to the surface
- Distilled or deionized water to hydrate the granular bentonite or make the slurry
- Optional—tremie pipe to get the sand, powdered bentonite, granular bentonite, and/or bentonite slurry down into the borehole
- Optional for permanent probes—flush mount or stick up monitoring well cover with concrete pad; flush mount covers come in various sizes (for example, 2- to 6-inch diameter), and may be traffic-rated if necessary
- Optional for semi-permanent probes—PVC cap or traffic cone to place over the probe
- Decontamination supplies—either steam cleaning or three-stage decontamination (water with phosphate-free detergent, water, and then distilled water)
- MultiRae five gas meter for health and safety monitoring during drilling

Procedures and Guidelines

This FOP describes the general procedures for installing and abandoning permanent and semi-permanent exterior soil vapor probes.

General guidelines are as follows:

- Select the appropriate soil vapor probe installation method based on site conditions and data quality objectives. Soil vapor probes may be installed using a variety of installation techniques including direct-push, hand auger, and AMS. The hand auger and AMS installation methods are only applicable to relatively shallow installation (for example, up to 10 to 15 ft bgs depending on the soil type).
- As with all intrusive site work, a utility clearance should be performed before installing soil vapor probes. It may also be necessary to acquire permits and site access.
- Although it is possible to install soil vapor probes while it is raining, care should be taken to ensure that water does not enter the borehole. Additionally, soil vapor sampling should not be performed until 48 hours after a significant rain event (defined as greater than 1 inch of rainfall).
- Before attempting installation of soil vapor probes, there should be an understanding of subsurface conditions (that is, soil types and depth to water) at the site:
  - When using the direct-push single rod and AMS installation methods, the rods are pushed into the ground without creating a hole beforehand. A soil core is not removed, so the soil types and depth to water cannot be assessed before selecting the probe screen depth. Additionally, the soils are displaced when the rod is pushed into the ground, which may increase the soil density around the probe.
  - The soil vapor probe screened interval, which includes the sand pack, should be above the capillary fringe and at least 5 feet bgs to avoid short circuiting with outdoor air. If there is impermeable ground cover (for example, concrete, asphalt), shallower sampling depths may be considered.
  - It may not be feasible to collect soil vapor from finer-grained or tight soils with little pore volume, such as clays.
- Soil vapor probes should not be installed into boreholes where groundwater or saturated soils have been encountered because the groundwater may be smeared on the sides of the borehole. Filling the borehole with sand to a level above the water table is not acceptable because it creates non-representative subsurface conditions.
- For expendable points on the direct-push tooling, it is optional to have an O-ring on the expendable point. If an O-ring is used, then the point-popper may be necessary to disengage the expendable point. If an O-ring is not used, then the expendable point may fall off if a void space is encountered, or soils may clog the expendable point holder.
- Permanent soil vapor probes can be finished at the ground surface with a stick up or flush mount cover and a concrete pad similar to groundwater monitoring wells. Semi-permanent soil vapor probes can be temporarily protected with a PVC cap or a traffic cone.
- Multiple depth soil vapor probes may be installed in the same borehole, or in separate holes 5 feet apart at the same location. Consideration should be taken when deciding how far apart to place the probe screens to avoid crossover of the volumes sampled (sphere of influence around the screen where the soil vapor sample is collected).
- Operation of direct-push machinery will be performed only by trained and licensed personnel.
- The reusable parts of the installation system must be decontaminated prior to use at each probe location. Steam cleaning is the preferred method of decontamination, but a three-stage wash is acceptable too. Once decontaminated, the reusable parts must be shown to be free of contaminates. The decontaminated reusable parts should be screened with a photoionization

detector to confirm they were completely decontaminated. Any part that does not pass must be decontaminated again until it passes.

- Equilibration time – after probe installation is completed, the subsurface must be allowed to equilibrate for at least 48 hours before the probe is purged, leak tested, or sampled.

Direct-Push Standard Installation Method–Single Depth

The following standard installation method can be used to install soil vapor probes at single depths:

1. Assemble the rods with the expendable point holder and expendable point.
2. Push the rods to the desired depth with a direct-push rig. Ensure that the final depth of the rods includes extra depth to include the length of the expendable point (typically approximately 2 inches) and the screened interval (for example, for a top screened depth of 5 ft bgs with a 6-inch-long screen that has 6-inches of sand above it, push the rods to 6 feet 2 inches bgs).
3. Assemble the probe by attaching the tubing to the screen. Use enough tubing so that at least 2 feet will be left above ground.
4. Thread the probe down the inside of the drive rod. Once the screen reaches the drive point, turn the tubing counterclockwise with a gentle downward force to thread the screen into the drive point. Test that the screen is seated by gently pulling up on the tubing.
5. Retract the rods the length of the screen plus 6 inches while pushing down on the Teflon tubing to ensure that the expendable point stays in place (and detaches from the rod) as the rod is being retracted. If the expendable point doesn't come off, then it may be necessary to unscrew the probe and use a point popper tool to release the expendable point.
6. Determine the volume of sand needed to fill the space around the screen plus an additional 6 inches above the screen. Pour the sand into the rods, and wiggle the Teflon tubing to ensure the sand gets down to the bottom:
   a. The probe tubing must be uncapped during this step or else the sand may bridge (that is, the air being displaced around the screen by the sand needs to escape out of the tubing).
   b. Measure the depth to the top of the sand pack to make sure it extends 6 inches above the top of the screen.
7. Retract the rods approximately 1 foot.
8. Recommended – Add a 6 to 12-inch layer of dry powdered bentonite on top of the sand pack. Determine the volume of dry powdered bentonite needed to create a 6 to 12-inch-long interval above the sand pack. Pour the powdered bentonite into the rods while wiggling the Teflon tubing to get the bentonite to the bottom.
9. Retract the rods several feet at a time, and fill the remainder of the hole with either granular bentonite hydrated in lifts or bentonite slurry.
10. Place a cap on the end of the tubing.
11. Complete at the surface as desired.

Direct-Push Modified Installation Method (Larger Diameter Rods)–Option for Multiple Depth Probes

Larger diameter rods (2.25-inch OD or larger) will be used for this method to provide extra room for putting sand and bentonite into the borehole; a tremie pipe will fit into the larger rods. The soil vapor probe will be lowered into the rods and will not be screwed into the expendable point on the outer rod. An additional smaller expendable point will be attached to the bottom of the probe screen before it is lowered into the rods. The following installation method may be used to install soil vapor probes at multiple depths in a single borehole:

1. Assemble the rods with the expendable point holder and expendable point.
2. Push the rods to the desired depth with a direct-push rig. Ensure that the final depth of the rods includes extra depth to include the length of both of the expendable points (typically approximately 2 inches each) and the screened interval (for example, for a top screened depth of 5 ft bgs with a 6-inch-long screen that has 6-inches of sand above it, push the rods to 6 feet 4 inches bgs).
3. Retract the drive rod approximately 1 foot. Use the point popper tool to release the expendable point.
4. Assemble the probe by attaching the tubing to the screen and screwing the smaller expendable point onto the bottom of the screen. Use enough tubing so that at least 2 feet will be left above ground.
5. Lower the probe down the inside of the drive rod until it touches the top of the larger expendable point.
6. Determine the volume of sand needed to fill the space around the screen plus an additional 6 inches above the screen. Pour the sand into the rods, and wiggle the Teflon tubing to ensure the sand gets down to the bottom; a tremie pipe can be used:
    a. The probe tubing must be uncapped during this step or else the sand may bridge (that is, the air being displaced around the screen by the sand needs to escape out of the tubing).
    b. Measure the depth to the top of the sand pack to make sure it extends 6 inches above the top of the screen. Retract the rods if necessary so that the bottom of the rod is above the sand pack.
7. Recommended – Add a 6 to 12-inch layer of dry powdered bentonite on top of the sand pack. Determine the volume of dry powdered bentonite needed to create a 6 to 12-inch-long interval above the sand pack. Pour the powdered bentonite into the rods while wiggling the Teflon tubing to get the bentonite to the bottom; a tremie pipe can be used.
8. Retract the rods several feet at a time, and fill the remainder of the hole with either granular bentonite hydrated in lifts or bentonite slurry; a tremie pipe can be used.
9. Multiple depth screens—additional shallower depth screen intervals may be installed into the borehole. A 3-inch layer of sand should be placed between the bentonite in the hole and where the bottom of the probe screen will be placed to prevent the bentonite from clogging the screen:
    a. Fill the hole with bentonite until 5 inches below where the bottom of the next shallow interval screen will be placed (leaving room for 3 inches of sand and 2 inches for the expendable point).
    b. Pour sand into the rods to create a 3-inch sand layer.
    c. Assemble the probe by attaching the tubing to the screen and screwing the smaller expendable point onto the bottom of the screen. Use enough tubing so that at least 2 feet will be left above ground.
    d. Lower the probe down the inside of the drive rod until it touches the sand layer.
    e. Follow steps 6 to 8 to create a sand pack around the screen, and then fill the hole with bentonite.

10. Place a cap on the end of the tubing. Be sure to label the tubing for multiple depth probe screens to distinguish between them.
11. Complete at the surface as desired.

Dual Tube Installation Method–Option for Multiple Depth Probes

The Geoprobe DT21/DT22 or DT325 dual tube system will be used to remove a soil core from the borehole before installing the soil vapor probe as follows:

1. Assemble the outer rods with the cutting shoe. Place the liner with core catcher into the outer rod.
2. Push the rods to the desired depth with a direct-push rig, removing soil cores along the way.
3. Remove a soil core below the cutting shoe for installation of the deepest interval probe screen.
4. Follow steps 4 to 11 in the previous section.

Hand Auger or Direct-Push Borehole Method

1. Use a hand auger or direct-push rig to create a borehole to the desired bottom probe depth. The hole must retain its integrity after the auger or rods are removed. Alternatively, a PVC pipe may be used to keep the borehole from collapsing.
2. Assemble the probe by attaching the tubing to the screen and screwing the smaller expendable point onto the bottom of the screen. Use enough tubing so that at least 2 feet will be left above ground.
3. Lower the probe down into the hole until it reaches the bottom.
4. Determine the volume of sand needed to fill the space around the screen plus an additional 6 inches above the screen. Pour the sand into the hole, and wiggle the Teflon tubing to ensure the sand gets down to the bottom; a tremie pipe can be used:
    a. The probe tubing must be uncapped during this step or else the sand may bridge (that is, the air being displaced around the screen by the sand needs to escape out of the tubing).
    b. Measure the depth to the top of the sand pack to make sure it extends 6 inches above the top of the screen.
5. Recommended – Add a 6 to 12-inch layer of dry powdered bentonite on top of the sand pack. Determine the volume of dry powdered bentonite needed to create a 6 to 12-inch-long interval above the sand pack. Pour the powdered bentonite into the hole while wiggling the Teflon tubing to get the bentonite to the bottom; a tremie pipe can be used.
6. Fill the remainder of the hole with either granular bentonite hydrated in lifts or bentonite slurry; a tremie pipe can be used.
7. Place a cap on the end of the tubing.
8. Complete at the surface as desired.

AMS Method

1. Assemble the rods with the expendable point holder and the dedicated gas vapor probe tip with screen and umbrella. Attach the tubing to the probe tip. The probe is driven into the ground with the tubing attached.

2. Push the rods to the desired depth with a slide hammer or hammer drill. Ensure that the final depth of the rods includes extra depth to include the 1-inch-long vapor probe tip.
3. Retract the rods with the removal jack 6 inches while pushing down on the Teflon tubing to ensure that the probe tip stays in place (and detaches from the rod) as the rod is being retracted.
4. Determine the volume of sand needed to fill the space around the screen plus an additional 6 inches above the screen. Pour the sand into the rods, and wiggle the Teflon tubing to ensure the sand gets down to the bottom:
    a. The probe tubing must be uncapped during this step or else the sand may bridge (that is, the air being displaced around the screen by the sand needs to escape out of the tubing).
5. Retract the rods with the removal jack approximately 1 foot.
6. Recommended – Add a 6 to 12-inch layer of dry powdered bentonite on top of the sand pack. Determine the volume of dry powdered bentonite needed to create a 6 to 12-inch-long interval above the sand pack. Pour the powdered bentonite into the rods while wiggling the Teflon tubing to get the bentonite to the bottom.
7. Retract the rods several feet at a time, and fill the remainder of the hole with either granular bentonite hydrated in lifts or bentonite slurry.
8. Place a cap on the end of the tubing.
9. Complete at the surface as desired.

Abandoning Semi-Permanent or Permanent Soil Vapor Probes

Check state regulations for soil vapor probe abandonment. Some states require the that entire soil vapor probe is over-drilled and removed. If so, a drill rig may be required if the probe is too deep to hand auger. Alternatively, some states may require filling the entire length of probe tubing with grout slurry which is very challenging with ¼-inch OD tubing. It is likely easier to over-drill and remove the entire probe.

1. If the probe was installed with a permanent cover, either flush-mount or stick-up, this cover must first be removed. Dig up the concrete pad and cover.
2. Dig a hole around where the tubing comes out of the ground to about 1-foot deep. This hole may already be accomplished from removal of a permanent cover.
3. Cut the tubing off below the ground surface, as low as possible in the hole.
4. Fill the hole with bentonite or soils, and repair the ground cover as necessary.

Quality Control and Quality Assurance

The field notes should be reviewed by the field quality manager at the end of each work day performed.

Attachments

- Soil Vapor Probe Diagram

References

Geoprobe Systems. 2017. *Implants Operation*. October 24.

Geoprobe Systems. 2006. *Direct Push Installation of Devices for Active Soil Gas Sampling & Monitoring. Technical Bulletin Number MK3098.* May.

JACOBS

PROJECT NUMBER	PROBE NUMBER SHEET OF DATE:

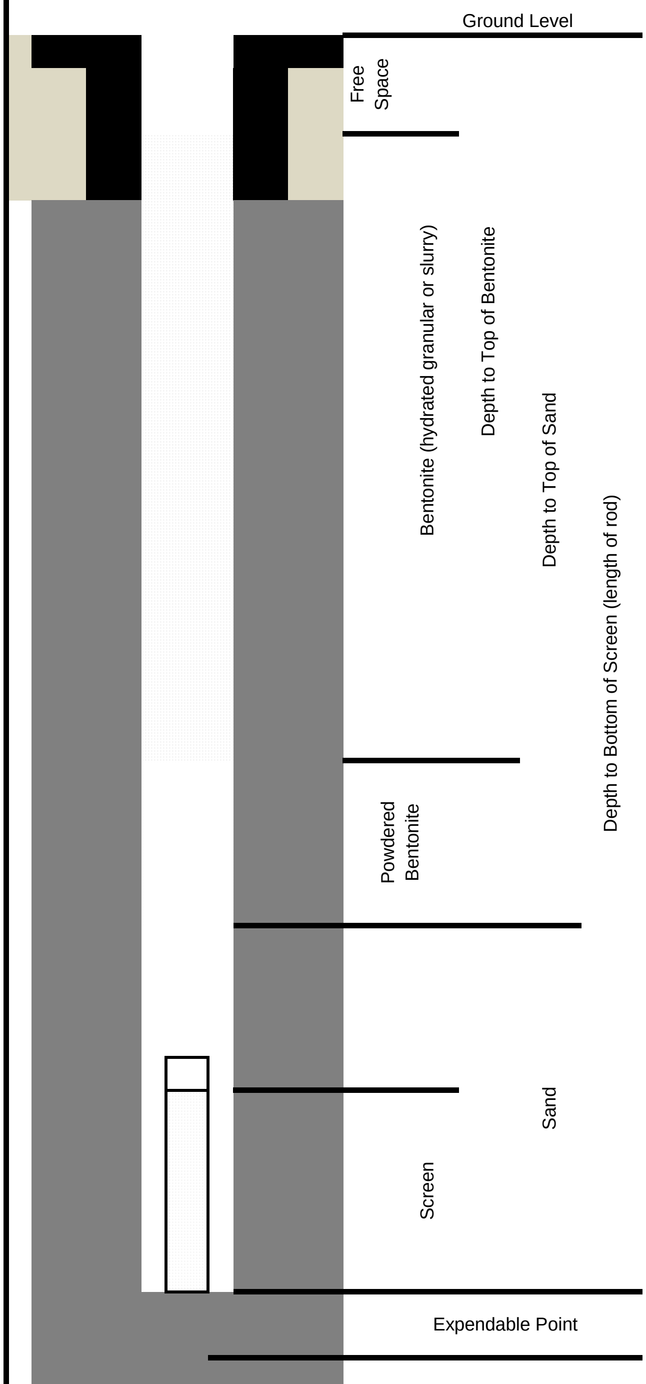
Soil Vapor Probe Diagram

PROJECT : LOCATION :

DRILLING CONTRACTOR :

DRILLING METHOD AND EQUIPMENT USED :

START : END: Installer :



Outer Diameter of Rod (in.) ________

Depth to Bottom of Screen (ft) ________

Length of Expendable Point (in.) ________

Screen Diameter (in.) / Length (in.) ________

Screen Mesh (in.) ________

Teflon Tubing Outer Diameter (in.) 0.25

Length of Sand Pack (in.) ________

Depth to Top of Sand (ft) ________

Length of Powdered Bentonite Seal (in.) ________

Depth to Top of Powdered Bentonite (ft) ________

Length of Bentonite (ft) ________

Depth to Top of Bentonite (ft) ________

Length of Free Space (in.) ________

Flush Mount Diameter. ________

Specifications (Quantity and Type)

Sand: ________

Bentonite: ________

Installation and Abandonment of Vapor Pins as Subslab Soil Vapor Probes

Purpose

This field operating procedure (FOP) presents general guidelines for installing and abandoning Cox-Colvin & Associates, Inc. (Cox-Colvin), Vapor Pins as subslab soil vapor probes.

Scope

This is a general description of how to install Vapor Pins as permanent or temporary subslab soil vapor probes, and how to abandon them when sampling is complete.

Equipment and Materials

Vapor Pin installation materials:

- Rotary hammer drill and drill bits (1.5-inch and 5/8-inch diameter).
  - The 5/8-inch diameter drill bit should be long enough to drill through the thickness of the slab.
  - The 1.5-inch drill bit is only necessary for installation of permanent subslab soil vapor probes so they can be finished with a flush-mount cover.
  - Optional: Cox-Colvin countersink drill bit. Can be used in high traffic areas to facilitate a true flush-mount installation of the stainless steel secure cover.
- Vacuum cleaner (shop-vac-type, with both a dust bag and high-efficiency particulate air [HEPA] filter) for removing concrete dust generated while drilling through the slab.
- A dust collection shroud to minimize dust during drilling. This can either be an on-board system that covers the whole drill bit, or a universal shroud that covers the hole.
- Recommended – field instrument such as a MultiRAE photoionization detector (PID) to measure total volatile organic compound (VOC) and carbon monoxide concentrations in the breathing zone for health and safety monitoring
- Power extension cord with multiple outlets and ground fault circuit interrupter
- Laser measuring tool, walking wheel, or measuring tape – to measure the location of the probe
- Assembled Vapor Pin (Vapor Pin and silicone sleeve as shown in Figure 1)

Figure 1. Assembled Vapor Pin

- Vapor Pin 3/4-inch bottle brush
- Vapor Pin white protective caps
- Vapor Pin installation/extraction tool
- Vapor Pin stainless-steel drilling guide (optional for permanent installation method)
- Traffic cone (optional for protecting stick-up probes)
- Dead-blow hammer or rubber mallet
- Vapor Pin black plastic or stainless-steel secure cover (optional for permanent probes)
- Vapor Pin spanner screwdriver for secure cover

Vapor Pin abandonment materials:

- Vapor pin installation/extraction tool
- Cement patch
- Trowel for applying cement patch

Procedures and Guidelines

This FOP describes the general guidelines for installing and abandoning Vapor Pins as subslab soil vapor probes.

Procedures for Installing Vapor Pins:

- A private utility clearance must be performed prior to drilling through the slab, as with all intrusive site work. The private utility clearance should be performed with a concrete scanner (small, handheld ground-penetrating radar unit designed for “seeing through” concrete slabs) to identify utilities, wire mesh, and/or rebar in the slab prior to drilling. A public utility locate may also be necessary depending on the site. The public utility clearance will only be completed outside of the building and/or property. In buildings where radiant floor tubing is in the slab, infrared scanning may also be necessary.
- Temporary stick-up soil vapor probes (**Figure 2**):
  - Drill a 5/8-inch diameter hole through the entire concrete slab with the rotary hammer drill while continuously vacuuming through the dust collection shroud.
  - Drill approximately 3 inches down into the subslab material to create a void space that is free of obstructions that might plug the probe during sampling.
- Permanent flush-mounted probes (**Figure 2**):
  - The slab must be at least 3.5 to 4 inches thick to install a permanent flush-mounted probe.
    - ☐ If the thickness of the slab is unknown, then the 5/8-inch diameter hole should be drilled through the entire concrete slab first determine the slab thickness.
    - ☐ However, if the slab is known to be at least 3.5 to 4 inches thick, then the 1.5-inch diameter hole may be drilled first.
  - Drill a 1.5-inch-diameter hole to a depth of 1.75 inches with the rotary hammer drill while continuously vacuuming through the dust collection shroud.
    - ☐ Optional - use the drilling guide to measure the hole depth.

- ☐ If a true flush-mount installation is required, the Cox-Colvin countersink bit can be used to drill both the 1.5-inch-diameter hole as well as the 2-inch diameter 1/8-inch deep counter sink.
- – Drill a 5/8-inch diameter hole through the rest of the concrete slab with the rotary hammer drill while continuously vacuuming through the dust collection shroud.
- – Drill approximately 3 inches down into the subslab material to create a void space that is free of obstructions that might plug the probe during sampling.

- Note the approximate thickness of the slab.
- Measure VOC concentrations in the breathing zone when drilling through the slab to ensure the project's health and safety requirements are met.

Figure 2. Permanent Flush-mounted Probe and Temporary Stick-up Probe

- Record the approximate thickness of the slab, the approximate depth drilled beneath the slab, and the observed subslab material in the field logbook.
- Clean out the hole with the Vapor Pin bottle brush and the shop vac.
- Install the Vapor Pin into the hole with the installation and extraction tool and dead-blow hammer or rubber mallet. During installation, the silicon sleeve will form a slight bulge between the slab and the Vapor Pin shoulder. Place the white protective cap on the Vapor Pin.
- Permanent flush-mounted probes – place either the black plastic or stainless steel secure cover over the Vapor Pin. Tighten the stainless steel secure cover using the spanner wrench.
- Temporary stick-up probes – place a traffic cone over the probe to protect people from tripping over it.
- Measure the location of the probe from two perpendicular exterior walls using the laser measuring tool, walking wheel, or measuring tape. Record the probe location in the field logbook or on a building layout figure.
- Wait at least 2 hours after installation is complete before purging, leak testing, and collecting subslab soil vapor samples to allow the subsurface to equilibrate.

Procedures for Abandoning Vapor Pins:

- Remove the traffic cone for temporary stick-up probes, or remove the black plastic cover or stainless steel secure cover with the spanner wrench.
- Remove the Vapor Pin from the hole with the installation/extraction tool.
- Fill the hole with concrete patch and smooth the surface with the trowel.

Quality Control and Quality Assurance

Verify the purge and leak testing passes controls before collecting the subslab soil vapor samples. The field notes should be reviewed by the field quality manager at the end of each work day performed.

References

U.S. Environmental Protection Agency. Office of Solid Waste and Emergency Response. 2015. *Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air*. June.

Cox-Colvin & Associates, Inc. (Cox-Colvin). 2016. *Standard Operating Procedure – Installation and Extraction of the Vapor Pin*. September.

Cox-Colvin & Associates, Inc. (Cox-Colvin). 2016. *Standard Operating Procedure – Countersink Drill Bit for Flush Mount Installation of the Vapor Pin*. August.

Soil Vapor Sampling from Exterior Soil Vapor Probes

Purpose

This field operating procedure (FOP) presents general guidelines for collecting soil vapor samples from temporarily-, semipermanently-, or permanently-installed exterior soil vapor probes. The number, location, analytical method (including sampling container), and sampling duration of soil vapor samples should be determined on a project-specific basis.

Scope

This is a general description of how to purge and leak test exterior soil vapor probes and then collect soil vapor samples. This FOP describes sampling with evacuated canisters and additional optional sampling methods including Bottle-Vacs, gas sampling bags, and sorbent tubes.

Equipment and Materials

Purge and Helium Leak Test:

- Three-way sampling manifold consisting of Swagelok gas-tight fittings with three valves and one vacuum gauge to attach the probe to the vacuum pump and the sample canister.
- Vacuum pump (battery-powered) with rotometer to control flow to 200 milliliters per minute (mL/min).
- Teflon tubing, 0.25-inch outer diameter.
- Swagelok nut and ferrule set (part #SS-400-NFSET) for purge and sampling train connections.
- Gas sampling bag (such as Tedlar brand) (1-liter or 3-liter) to collect the purged soil vapor so the approximate volume of purged soil vapor can be measured and field screening can be performed on the purged vapor.
- Wrenches and screwdriver, various sizes as needed for connecting fittings. A 9/16-inch wrench fits the 0.25-inch Swagelok fittings.
- Helium enclosure to fit around the flush-mount probe cover for permanent soil vapor probes or over the drill rod for temporary probes.
- Helium - canister of high-purity helium with 0.5-liter per minute flow regulator.
- MGD Dielectric Helium Detector.
- Photoionization detector (PID; MiniRae or MultiRae) to monitor breathing zone volatile organic compound (VOC) concentrations. It is also optional to collect field measurements of total VOCs from the purged soil vapor; may warn the laboratory if high concentrations are detected so they can dilute the sample before analysis.
- LandTec GEM Landfill Gas Meter (optional) to collect field measurements of oxygen, carbon dioxide, and methane.

Soil vapor sampling with evacuated canisters:

- Stainless-steel sample canister(s) certified clean and evacuated (canisters are cleaned, evacuated, and provided by the laboratory.)
- Flow controller(s) set at desired sampling rate. (Flow controllers are cleaned, set, and provided by the laboratory.)
- Analog pressure gauge dedicated to the canister may be permanently attached to either the canister or flow controller. This pressure gauge will be used to monitor the canister pressure during sampling.
- Digital pressure gauge with a -30 to 0 inch mercury (Hg) range, and 0.50 inches Hg accuracy that should be verified annually. This pressure gauge should have a Swagelok 1/4-inch female connection because it will be used to measure the initial and final canister pressure. Digital gauges should not be shared between soil vapor samples and air samples (indoor, outdoor, or crawlspace) to prevent cross-contamination.
- Wrenches and screwdriver, various sizes as needed for connecting fittings. A 9/16-inch wrench fits the 0.25-inch Swagelok fittings, which most canisters and flow controllers have.
- Swagelok nut and ferrule set (part #SS-400-NFSET) to connect tubing to the sampling manifold.
- T-connector (provided by the laboratory) to collect simultaneous duplicate samples.
- Shipping container, suitable for protection of canister(s) during shipping. Typically, strong cardboard boxes are used for canister shipment. The canisters should be shipped to the laboratory in the same shipping container(s) in which they were received.

Alternative soil vapor sampling methods:

- Bottle-Vacs:
  - Bottle-Vac(s) (evacuated, and provided by the laboratory).
  - Flow controller set at desired sampling rate. (Flow controllers are cleaned, set, and provided by the laboratory.)
  - Digital pressure gauge with a -30 to 0 inch Hg range, and 0.50 inches Hg accuracy which should be verified annually. This pressure gauge should have a quick-connect connection because it will be used to measure the initial and final Bottle-Vac pressure. Digital gauges should not be shared between soil vapor samples and air samples (indoor, outdoor, or crawlspace) to prevent cross-contamination.
  - T-connector (provided by the laboratory) for collecting simultaneous duplicate samples.
  - Shipping container, suitable for protection of Bottle-Vac(s) during shipping. The Bottle-Vac(s) should be shipped to the laboratory in the same shipping container(s) in which they were received.
- Gas sampling bag (such as Tedlar brand):
  - Gas sampling bag
  - Lung box
- Sorbent Tubes:
  - Sorbent tube(s) (provided by the laboratory. Include one extra to use for flow calibration purposes.

– SKC flow calibrator 5 to 500 mL/min to measure the exact flow rate while sampling.

Procedures and Guidelines

This FOP describes the general guidelines for purging and leak testing exterior soil vapor probes, then collecting soil vapor samples. Purging, leak testing, and sampling information should be recorded in the field logbook and on the attached "Soil Vapor Sampling Log" form.

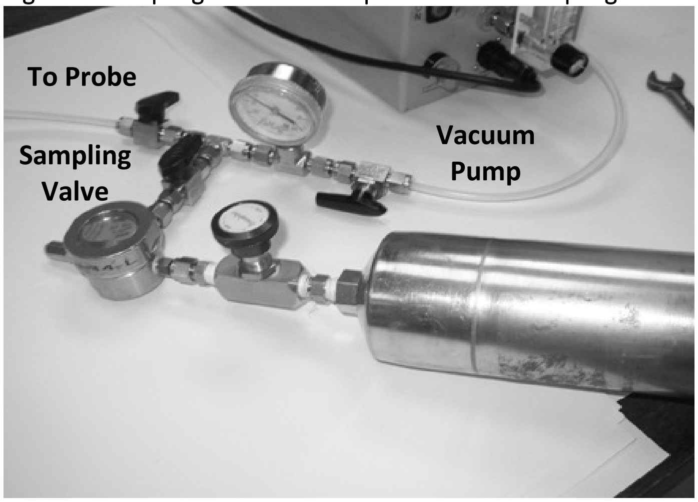
General Guidelines

- Wait at least 48 hours after installation of permanent or semi-permanent soil vapor probes and at least 30 minutes after installation of temporary soil vapor probes with the Geoprobe post-run tubing system before purging, leak testing, and sampling the probes to allow the subsurface to equilibrate. Check local guidance and regulations to confirm these are appropriate equilibration times for the soil vapor probes.
- Soil vapor sampling should not be performed until 48 hours after a significant rain event (defined as greater than 1 inch of rainfall). Check local guidance and regulations to confirm these are appropriate waiting periods for sampling after precipitation.

System Setup:

1. Remove the protective cover (such as a flush-mount cover, or semi-permanent polyvinyl chloride [PVC] cover) on the soil vapor probe (if present).
2. Place the helium enclosure over the soil vapor probe and adjust it so that it will allow a buildup of helium in the enclosure. The enclosure should not be sealed tightly, and there should be an exhaust for the helium so pressure does not build up in the enclosure. Where the ground surface is soft, the helium leak-check enclosure can be pressed down slightly into the ground surface. Where the ground surface is hard (for example, asphalt), use a sealing material (foam tape or modeling clay) and apply a slight downward pressure to achieve a buildup of helium in the leak-check enclosure.
3. Remove the cap from the probe tubing and connect the probe tubing to the sampling manifold.
4. Attach the vacuum pump to the sampling manifold using Teflon tubing and Swagelok nut and ferrule sets.
5. System set up for canister sampling:
   - 5.1. Measure the initial canister pressure with the digital pressure gauge. The initial pressure should be between -28 to -30 inches Hg. If it is less than -26 inches Hg, do not use the canister for sampling. If it is between -28 to -26 inches Hg only use the canister if there are no other spare canisters available. In the field log, record the canister identification (ID), flow controller ID, initial vacuum, desired flow rate, sample location information, and all other information pertinent to the sampling effort.
   - 5.2. Connect the flow controller and analog pressure gauge to the canister. When the flow controller and pressure gauge are attached correctly they will not move separately from the canister (they will not spin around).
   - 5.3. Connect the canister via the flow controller to the sampling manifold.

Figure 1. Sampling Manifold Setup for Canister Sampling



Manifold Vacuum Leak-Check:

The purpose of the manifold leak test is to make sure the connections in the sampling train are air tight. For canister sampling, the connections on the sampling manifold through the flow controller to the valve on the canister will be leak tested (Figure 1). For duplicate samples, the whole assembly with the T-connector should be vacuum leak tested. For alternative sampling methods, the connections on the sampling manifold will be leak tested.

1. Close the valve to the probe, open the valve to the pump. For canister sampling, open the sampling valve to the canister on the manifold; the valve on the canister is closed.
2. Turn the pump on and wait for the gauge on the manifold to reach approximately -10 inches Hg. Close the valve to the pump and turn the pump off. The sampling train is now a closed system.
3. Wait approximately 30 seconds to ensure that the vacuum is maintained and there are no leaks (as shown by the stability of the pressure gauge).
4. If there is a visible loss of vacuum, tighten the connections and redo the leak test until it passes.

System Purge and Helium Leak Check:

A purge of the soil vapor probe and sampling manifold system is required before taking each sample. The helium leak-check procedure is also performed during this step. This helium leak check will verify the integrity of the probe seal, sampling adapter (or post-run tubing [PRT] adapter if using the Geoprobe PRT system) seal, as well as the probe and ground interface; this is accomplished by completing the following steps:

1. Start the flow of helium under the leak-check enclosure. Let the helium fill the enclosure for a couple of minutes.
2. Turn the helium leak detector on while in outdoor air and ensure that the detector exposed to helium because it does a zero calibration every time it is turned on.
3. Verify that the helium concentration inside the leak-check enclosure is more than 10 percent by placing the probe of the helium detector into the enclosure.
4. Purging is carried out by pulling soil vapor through the system at a rate of 200 mL/min for a period sufficient to achieve a purge volume that equals 3 to 5 dead volumes (internal volume) of the in-ground annular space, sample line, and sampling manifold system.

4.1. When calculating the dead volume, be sure to consider the inside diameter and length of the Teflon sample tubing, as well as the probe outside diameter and retraction distance for the annular space of temporary probes.

4.2. For permanent probes, calculate the volume of the annular space using a nominal 30 percent porosity for the sand pack.

4.3. The gas sampling bag should be attached to the vacuum pump exhaust to collect the purged soil vapor so the approximate volume of purged soil vapor can be measured and field screening can be performed on the purged vapor.

5. Open the sample valve and the purge valve and start the vacuum pump. Verify that the flow rate is still 200 mL/min.

6. If there is shallow groundwater in the area, carefully watch the tubing as the pump is turned on. If water is observed in the sample tubing, shut the pump off immediately. Soil vapor collection will not be feasible if the probe is in contact with water.

7. Monitor the purging vacuum on the sampling manifold pressure gauge. The purging vacuum should not exceed -7 inches Hg; if it does, turn the pump off, close the valve to the pump, and wait to see if there is recovery. If there is no noticeable change in vacuum after several minutes, then there is an insufficient amount of soil vapor to collect a sample and the vacuum is too great to collect a soil vapor sample. Several factors can cause this situation, including the following (consult with the project manager and take corrective action):

7.1. The soil formation is too “tight” (that is, high clay or moisture content). Try using a lower flow rate (temporary or permanent probe). Try a different depth or location (temporary probe).

7.2. The probe screen, or annular space for temporary probes, may be in water even if the water has not yet come up in the tubing. Soil vapor sampling is not feasible if the probe is in contact with water. Try a different depth or location (temporary probe). Try sampling the probe again in dryer conditions (permanent probe).

7.3. With a temporary probe system (such as the Geoprobe PRT system), the expendable tip may not have released when the drive rod was retracted. Try retracting the probe a little further, or use the point run popper to poke the tip loose.

7.4. If purging cannot be completed without creating a vacuum exceeding -7 inches Hg, then the probe cannot be sampled.

8. Measure the helium concentration in the enclosure several times during purging to calculate an average concentration in the enclosure during the purge duration.

9. At the end of the calculated purge time and after the system is verified to be leak free, turn off the pump, close the valve to the pump, and close the valve to the probe. Close the valve on the gas sampling bag and remove the bag from the pump.

10. Measure the helium concentration in the purged soil vapor in the gas sampling bag. The helium concentration in the purged soil vapor must be less than 5 percent of what it was in the helium enclosure during purging to pass the leak test.

10.1. For example, if the helium concentration in the purged soil vapor is 2,300 parts per million (ppm), that is 0.23 percent, and the average helium concentration in the enclosure was 35 percent, then the percentage leak is 0.66 percent [0.23/35*100 = 0.66 percent]).

10.2. If the probe fails the leak check, then corrective action is required; this includes first checking the fittings and connections and trying another purge and leak check. It may also be necessary to remove the soil vapor probe, if it is temporary, and re-install it in a nearby location.

10.3. Helium leak detectors may be sensitive to high concentrations of methane or other atmospheric gasses. If high methane concentrations are expected to be present in the soil vapor, then caution should be used with this technique, as false positive readings may be encountered during leak testing. Use a Landtec GEM Landfill Gas Meter to determine if methane is present in the soil vapor.

11. Optional - Field readings of total VOCs with a PID, and/or oxygen, carbon dioxide, and methane with a LandTec GEM Landfill Gas meter may be performed on the purged soil vapor.

12. Record the purge and leak-check information on the Soil Vapor Sampling Log (attached).

Canister Sampling:

1. For extended duration samples (for example, 8- or 24-hour)

    1.1. Remove the sampling manifold by detaching the canister from the manifold, then detaching the probe tubing from the manifold and quickly attaching it to the canister via the flow controller.

    1.2. Attach the sign (identifying the canisters as an air sample, saying “Do Not Disturb” and providing contact information) to the canister.

    1.3. Make sure the canister will be secure at the sampling location; place traffic cones around the probe and canister if necessary.

2. To begin sampling, open the canister valve one full turn and record the sample start time. (For grab samples, the canister will still be attached to the sampling manifold.)

3. Monitor the canister pressure on the analog gauge (if present) several times during the sample period, to ensure the canister is filling at the desired rate and the final canister pressure does not fall to 0 inch Hg.

4. At the end of the sample period, close the canister valve and record the sample end time. Detach the canister from the manifold or probe tubing.

5. Measure the final canister pressure with the digital pressure gauge. The final pressure should be between -10 to -2 inches Hg. If it is 0 inch Hg, do not submit the sample for analysis. If it is between -2 and 0 inch Hg re-deploy the sample if possible; if not submit it to the laboratory for analysis but make sure it is received with some residual negative pressure.

6. Replace the protective cap on the canister.

7. Duplicate samples should be collected simultaneously with a dedicated T-connector.

    7.1. Grab sample duplicates should be collected by attaching the T-connector to each canister and then connecting one flow controller to the top of the T-connector. (If there was a flow controller on each canister, then the sampling flow rate would exceed the maximum allowable flow rate of 200 mL/min.) The duplicate sample will take twice as long to collect.

    7.2. Extended duration samples should be collected by attaching a flow controller to each canister and then connecting the T-connector to each flow controller. (If only one flow controller was used, then the sampling duration would be twice as long.)

Bottle-Vac Sampling:

1. Measure the initial pressure with the digital pressure gauge. The initial pressure should be between -28 to -30 inches Hg. If it is less than -26 inches Hg, do not use the Bottle-Vac for sampling. If it is between -28 to -26 inches Hg, only use the Bottle-Vac if there are no other spares available. In the

field log record the Bottle-Vac ID, flow controller ID, initial vacuum, desired flow rate, sample location information, and all other information pertinent to the sampling effort.

2. For extended duration samples (for example, 8- or 24-hours):
    2.1. Remove the sampling manifold and attach the probe tubing to the flow controller.
    2.2. Attach the sign (identifying the canisters as an air sample, saying “Do Not Disturb” and providing contact information) to the canister.
    2.3. Make sure the canister will be secure at the sampling location; place traffic cones around the probe and canister if necessary.
3. For grab samples – Attach the flow controller to the sampling valve on the sampling manifold.
4. To begin sampling, attach the Bottle-Vac to the to the flow controller via the quick-connect and record the sample start time.
5. At the end of the sample period, detach the Bottle-Vac from the flow controller and record the sample end time. Detach the flow controller from the probe tubing or sampling manifold.
6. Measure the final Bottle-Vac pressure with the digital pressure gauge. The final pressure should be between -10 to -2 inches Hg. If it is 0 inch Hg, do not submit the sample for analysis. If it is between -2 and 0 inch Hg, re-deploy the sample if possible; if not submit it to the laboratory for analysis but make sure it is received with some residual negative pressure.
7. Duplicate samples should be collected simultaneously with a dedicated T-connector as described in the Canister Sampling section of this FOP.

Tedlar Bag Sampling:

1. Detach the vacuum pump from the sampling manifold and attach it to the lung box, then attach the probe tubing via the sampling manifold to the lung box influent.
2. Place a Tedlar bag in the lung box using dedicated Teflon and flexible silicon tubing.
3. To begin sampling, turn the pump on and record the sample start time.
4. Turn the pump off when the Tedlar bag is full and record the sample end time. The Tedlar bag should only be filled 50 percent if it will be shipped via plane.
5. Detach the probe tubing and vacuum pump from the lung box.

Sorbent Tube Sampling:

1. Disconnect the pump tubing from the manifold.
2. Attach a spare sorbent tube provided by the lab to the vacuum pump tubing using a 1/4-inch Swagelok union or flex tubing. Do not use a tube that is intended for sampling. Be sure to attach the sorbent tube so that the flow direction is correct.
3. Attach the SKC flow calibrator to the vacuum pump exhaust.
4. Turn on the vacuum pump and adjust the flow to achieve the desired flow rate of 200 mL/min using the flow calibrator.
5. Remove the spare sorbent tube from the pump tubing.
6. Remove the end caps from the sorbent tube to be used for sampling and attach it to the vacuum pump tubing using a 1/4-inch Swagelok union or flex tubing. Be sure to attach the sorbent tube so that the flow direction is correct. Record the sample tube ID on the field form.

7. Attach the other end of the sorbent tube to the sample manifold where the pump tubing used to be attached using either Swagelok fittings or flex tubing.
8. Make sure both the probe valve and the vacuum pump valve are open and the sampling valve is closed.
9. Start the pump and record the start time. Using flow calibrator, record initial flow rate.
10. If the flow rate starts to drop, it may indicate that the sorbent tube is becoming plugged with water. Stop the vacuum pump and record the end time.
11. After the required amount of time, record the final flow rate from the flow calibrator. Turn off the pump and remove the sorbent tube. Record the end time.
12. Replace the end caps on the sorbent tube. Replace the sorbent tube into the container it was received in.

After Sample Collection is Completed:

1. Disassemble the sampling system and replace the cap on the probe tubing.
2. For permanent probes - replace the protective cover (such as a flush-mount cover, or semi-permanent PVC cover) on the soil vapor probe (if present).
3. Fill out all appropriate documentation (chain of custody, sample tags) and return samples and equipment to the laboratory in the same shipping container in which they were received. Do not place sticky labels or tape on surface of the canister.
4. Canisters, Bottle-Vacs, and Tedlar bags should not be cooled during shipment. DO NOT put ice in the shipping container. Sorbent tubes may require ice for shipping.

Quality Control and Quality Assurance

- Canisters supplied by the laboratory must follow the performance criteria and quality assurance prescribed in U.S. Environmental Protection Agency (EPA) Method TO-14/15 for canister cleaning, certification of cleanliness, and leak checking.
- Flow controllers supplied by the laboratory must follow the performance criteria and quality assurance prescribed in EPA Method TO-14/15 for flow controller cleaning and adjustment.
- Field duplicates and trip blanks (sorbent tube methods only) may be required. Check the work plan for frequency.

Attachments

- Soil Vapor Sampling Log
- Sign identifying the canisters or Bottle-Vacs as an air sample, saying "Do Not Disturb" and providing contact information.

References

U.S. Environmental Protection Agency (EPA). Office of Solid Waste and Emergency Response. 2015. *Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air*. June.

Soil Vapor Sampling Log

Project: Sampler:

Sample Location Information

Property ID/Address: __________

Condition of ground in the surrounding area: __________

Location ID: __________ Sample ID: __________

Sample Location Description:

Soil Vapor Probe Leak Checking and Sampling Log

Manifold Leak Check

Manifold leak check (procedure: ensure manifold holds pressure at -10 "Hg for 30 seconds). If using a pelican-case pump, open the lid during leak check to ensure all interior pieces are in-tact. *Pass* *Fail*

Describe corrective measures taken to pass the manifold leak test: __________

Soil Vapor Probe Helium Leak Check and Purge Results

Purge rate (mL/Min): __________ Helium Conc. in the Purged Vapor: __________

Start and End Times: __________ Calculated leak percentage: __________

Purge Vacuum ("Hg): __________ Probe Leak Check Result*: *Pass* *Fail*

Avg. Helium Conc. in the Enclosure: __________

Total Volume Purged (L):

*The soil vapor probe passes the leak test if the helium concentration in the purged soil vapor is less than 5% of what it was in the helium enclosure during purging. For example, if the helium concentration in the purged soil vapor is 2,300 ppm that is 0.23%, and the average helium concentration in the enclosure was 35%, then the percentage leak is 0.66% [0.23/35*100 = 0.66%]). Do NOT collect a soil vapor sample if the leak check fails.

Field Analysis (required readings are determined on a project-specific basis. Fill in all that are necessary):

MiniRAE or MultiRAE Photoionization Detector				LandTec GEM Landfill Gas Meter
Total VOCs (ppm): ______	O_2 (%): ______			O2 (%): ______
H_2S (ppm): ______	LEL (%): ______			CO2 (%): ______
CO (ppm):				CH4 (%):

Sampling Information

Evacuated Canister or Bottle-Vac

Canister Size (L): __________ Initial Pressure (" Hg): __________

Canister ID: __________ Start Date and Time: __________

Flow Controller ID: __________ End Date and Time: __________

Sampling Rate (mL/min, hours): __________ Final Pressure (" Hg): __________

Sampling Vacuum ("Hg):

Tedlar Bag

Tedlar Bag size (L): __________ Sampling Rate (mL/min): __________

Sampling Date: Sampling Start and End Times:

Sorbent Tube

Sorbent Tube type and size: __________ Sampling Date: __________

Sorbent Tube ID: __________ Sampling Start and End Times: __________

Initial Flow Rate (mL/min): __________ Final Flow Rate (mL/min): __________

Calculated Sampling Volume:

Weather Conditions and Additional Notes

Weather Conditions During Sampling: __________

____

Additional Notes: __________

Subslab Soil Vapor Sampling from Vapor Pins

Purpose

This field operating procedure (FOP) presents general guidelines for collecting subslab soil vapor samples from Cox-Colvin & Associates, Inc. (Cox-Colvin), Vapor Pins; methods for purging and leak-checking the Vapor Pins are also included in this FOP. The number, location, analytical method (including sampling container), and sampling duration of subslab soil vapor samples should be determined on a project-specific basis. A building survey is typically performed before sampling to obtain building characteristic information.

Scope

This is a general description of how to purge and leak test Vapor Pins and then collect subslab soil vapor samples. This FOP describes sampling with evacuated canisters and additional optional sampling methods including Bottle-Vacs, Tedlar bags, and sorbent tubes.

Equipment and Materials

Purge and water dam leak-check:

- Vacuum pump with rotometer to control flow to 200 milliliters per minute (mL/min)
- Water
- Vapor Pin water dam
- Volatile organic compound (VOC)-free modeling clay (like Play-Doh)
- Paper towels
- Turkey baster or large plastic syringe (for removing water from the water dam)
- Three-way sampling manifold consisting of Swagelok gas-tight fittings with three valves and one vacuum gauge to attach the probe to the vacuum pump and the sample canister
- Teflon tubing, 0.25-inch outer diameter
- Flexible silicon tubing (3/16-inch inner diameter to connect Teflon tubing from Vapor Pin)
- 1-liter Tedlar bag to collect the purged soil vapor so: (1) it is not discharged into the building; (2) the approximate volume of purged soil vapor can be measured; and (3) field screening can be performed on the purged soil vapor
- Recommended – field instrument such as a MultiRAE photoionization detector (PID) to measure total volatile organic compound (VOC) and carbon monoxide concentrations in the breathing zone for health and safety monitoring. It is also optional to collect field measurements of total VOCs from the purged soil vapor; may warn the laboratory if high concentrations are detected so they can dilute the sample before analysis.
- Optional – LandTec GEM Landfill Gas Meter to collect field measurements from the purged soil vapor of oxygen, carbon dioxide, and methane

Subslab soil vapor sampling with evacuated canisters:

- Stainless-steel sample canister(s) certified clean and evacuated (canisters are cleaned, evacuated, and provided by the laboratory.) Note that separate canisters of the same size may be designated by the laboratory for use in collecting subslab soil vapor samples versus indoor air, outdoor air, and crawlspace air samples and may been certified in different manners. It is important to make sure that canisters are used for their designated sample type.
- Flow controller(s) set at desired sampling rate. (Flow controllers are cleaned, set, and provided by the laboratory.)
- Analog pressure gauge dedicated to the canister may be permanently attached to either the canister or flow controller. This pressure gauge will be used to monitor the canister pressure during sampling.
- Digital pressure gauge with a -30 to 0 inch mercury (Hg) range, and 0.50 inch Hg accuracy, which should be verified annually. This pressure gauge should have a Swagelok 1/4-inch female connection because it will be used to measure the initial and final canister pressure. Digital gauges should not be shared between soil vapor samples and air samples (indoor, outdoor, or crawlspace) to prevent cross-contamination.
- Wrenches and screwdriver, various sizes as needed for connecting fittings. A 9/16-inch wrench fits the 0.25-inch Swagelok fittings, which most canisters and flow controllers have.
- Swagelok nut and ferrule set (part #SS-400-NFSET) to connect tubing to the sampling manifold
- T-connector (provided by the laboratory) for collecting simultaneous duplicate samples.
- Shipping container, suitable for protection of canister(s) during shipping. Typically, strong cardboard boxes are used for canister shipment. The canisters should be shipped to the laboratory in the same shipping container(s) in which they were received.
- Optional – signs identifying the canisters as an air sample, saying "Do Not Disturb" and providing contact information. The sign can be laminated and attached to the canister with a zip tie. (These signs are for extended duration samples only because grab samples will not be left unattended.)

Alternative subslab soil vapor sampling methods:

- Bottle-Vacs:
  - Bottle-Vac(s) (evacuated, and provided by the laboratory.)
  - Flow controller set at desired sampling rate. (Flow controllers are cleaned, set, and provided by the laboratory.)
  - Digital pressure gauge with a -30 to 0 inch Hg range, and 0.50 inch Hg accuracy, which should be verified annually. This pressure gauge should have a quick-connect connection because it will be used to measure the initial and final Bottle-Vac pressure. Digital gauges should not be shared between soil vapor samples and air samples (indoor, outdoor, or crawlspace) to prevent cross-contamination.
  - T-connector (provided by the laboratory) for collecting simultaneous duplicate samples.
  - Shipping container, suitable for protection of Bottle-Vac(s) during shipping. The Bottle-Vac(s) should be shipped to the laboratory in the same shipping container(s) in which they were received.
  - Optional – signs identifying the Bottle-Vac(s) as an air sample, saying "Do Not Disturb" and providing contact information. The sign can be laminated and attached to the Bottle-Vac(s)

with a zip tie. (These signs are for extended duration samples only because grab samples will not be left unattended.)

- Tedlar Bags:
  - Tedlar Bags
  - Lung box
- Sorbent Tubes:
  - Sorbent tube(s) (provided by the laboratory. Include one extra to use for flow calibration purposes.
  - SKC flow calibrator 5 to 500 mL/min to measure the exact flow rate while sampling

Procedures and Guidelines

This FOP describes the general guidelines for purging and water dam leak testing Vapor Pins, then collecting subslab soil vapor samples using evacuated canisters. Purging, leak testing, and sampling information should be recorded in the field logbook and on the attached form "Subslab Soil Vapor Sampling Log".

System Setup:

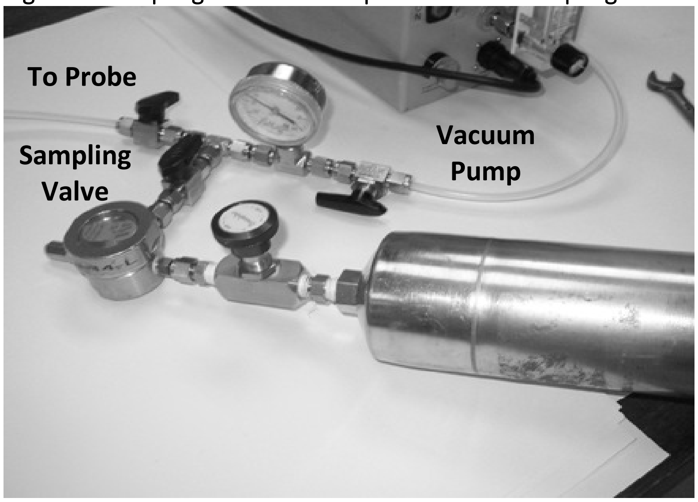
1. Wait at least 2 hours after probe installation is complete before collecting subslab soil vapor samples to allow the subsurface to equilibrate.
2. Remove the secure cover and the white cap on the Vapor Pin.
3. Attach a new piece of flex tubing, approximately 1 inch long, to the barbed fitting at the top of the Vapor Pin. Then attach 0.25-inch Teflon tubing to the flex tubing.
4. Place the water dam over the subslab probe by threading the Teflon tubing through the hole of the water dam. Press the water dam down so it seals on the concrete slab using VOC-free modeling clay. Fill with water. The water level should be above the connection between the flex tubing and the Teflon tubing.
5. Attach the other end of the Teflon tubing to the sampling manifold using a Swagelok nut and ferrule set.
6. Attach the vacuum pump to the sampling manifold using Teflon tubing and Swagelok nut and ferrule sets.
7. System set up for canister sampling:

   7.1. Measure the initial canister pressure with the digital pressure gauge. The initial pressure should be between -28 to -30 inches Hg. If it is less than -26 inches Hg do not use the canister for sampling. If it is between -28 to -26 inches Hg only use the canister if there are no other spare canisters available. In the field log record the canister identification (ID), flow controller ID, initial vacuum, desired flow rate, sample location information, and all other information pertinent to the sampling effort.

   7.2. Connect the flow controller and analog pressure gauge to the canister. When the flow controller and pressure gauge are attached correctly they will not move separately from the canister (they will not spin around).

   7.3. Connect the canister via the flow controller to the sampling manifold.

Figure 1. Sampling Manifold Setup for Canister Sampling



Manifold Vacuum Leak Check:

1. The purpose of the manifold leak test is to make sure the connections in the sampling train are air tight.
2. For canister sampling, the connections on the sampling manifold through the flow controller to the valve on the canister will be leak tested (Figure 1); for duplicate samples the whole assembly with the T-connector should be vacuum leak tested. For alternative sampling methods, the connections on the sampling manifold will be leak tested.
3. Close the valve to the probe, open the valve to the pump. For canister sampling open the sampling valve to the canister on the manifold; the valve on the canister is closed.
4. Turn the pump on and wait for the gauge on the manifold to approximately -10 inches Hg. Close the valve to the pump and turn the pump off. The sampling train is now a closed system.
5. Wait approximately 30 seconds to ensure that the vacuum is maintained and there are no leaks (as shown by the stability of the pressure gauge).
6. If there is a visible loss of vacuum, tighten the connections and redo the leak test until it passes.

Purge and Water Dam Leak-Check

8. Purging and leak testing the soil vapor probe is required before sampling every time. Purging removes ambient air from the sampling train and stagnant soil vapor around the probe.
9. Open the valves to the pump and probe, and attach the Tedlar bag to the pump effluent. The sampling valve should be closed.
10. Turn the pump on with the flowrate at 200 mL/min and purge for approximately 5 minutes to fill the 1-liter Tedlar bag.
11. Monitor the purging vacuum on the sampling manifold pressure gauge. The purging vacuum should not exceed -7 inches Hg; if it does, turn the pump off, close the valve to the pump, and wait to see if there is recovery.
    11.1. The probe may be clogged or there may be water or tight soils present beneath the slab that do not allow for soil vapor sampling.
    11.2. Try unclogging the probe with a thin metal rod, or remove the probe and check for blockages.

11.3. If purging cannot be completed without creating a vacuum exceeding -7 inches Hg, then the probe cannot be sampled.

12. Observe the water level in the water dam for indications that water is entering the subslab (drop in water level or bubbles). If there is, the Vapor Pin failed the leak check and corrective action is required. The leak test must be performed again after corrective actions are taken until the Vapor Pin passes the leak test. Note: Water level might drop slightly because of absorption into the concrete.

13. There are five corrective action options (first remove the water from the water dam with a turkey baster):

    13.1. Remove the Vapor Pin, clean out the drilled hole thoroughly, replace the silicone sleeve with a new one, and reinstall.

    13.2. Fill in visible concrete cracks inside the drilled hole with quick-setting cement and, after allowing the cement to cure, retest.

    13.3. Try fortifying the Vapor Pin seal by adding modeling clay to the base of the Vapor Pin. This temporary repair is only acceptable if grab samples will be collected; permanent repairs must be made for extended duration samples (for example, 8- or 24-hour) because the clay may dry and crack.

    13.4. Add Teflon tape to the barbed connector and the Teflon tubing, reattach the flex tubing and the Teflon tubing, make sure that all the fittings are tight and repeat the purge and leak-check procedure.

    13.5. If the previous options fail, then the Vapor Pin should be abandoned.

14. Optional - Field readings of total VOCs with a PID, and/or oxygen, carbon dioxide, and methane with a LandTec GEM Landfill Gas meter may be performed on the purged soil vapor. Perform readings outside of the building so that soil vapor is not released into indoor air.

15. Record the purge and leak-check information on the Subslab Soil Vapor Sampling Log.

Canister Sampling:

1. For extended duration samples (for example, 8- or 24-hour)

    1.1. Remove the sampling manifold by detaching the canister from the manifold, then detaching the probe tubing from the manifold and quickly attaching it to the canister via the flow controller.

    1.2. Attach the sign (identifying the canisters as an air sample, saying “Do Not Disturb” and providing contact information) to the canister.

    1.3. Make sure the canister will be secure at the sampling location; place traffic cones around the probe and canister if necessary.

2. To begin sampling, open the canister valve one full turn and record the sample start time. (For grab samples the canister will still be attached to the sampling manifold.)

3. Monitor the canister pressure on the analog gauge (if present) several times during the course of the sample period to ensure the canister is filling at the desired rate and the final canister pressure does not fall to 0 inch Hg.

4. At the end of the sample period, close the canister valve and record the sample end time. Detach the canister from the manifold or probe tubing.

5. Measure the final canister pressure with the digital pressure gauge. The final pressure should be between -10 to -2 inches Hg. If it is 0 inch Hg, do not submit the sample for analysis. If it is between -2 and 0 inches Hg, re-deploy the sample if possible; if not, submit it to the laboratory for analysis but make sure it is received with some residual negative pressure.
6. Replace the protective cap on the canister.
7. Duplicate samples should be collected simultaneously with a dedicated T-connector.
    7.1. Grab sample duplicates should be collected by attaching the T-connector to each canister and then connecting one flow controller to the top of the T-connector. (If there was a flow controller on each canister, then the sampling flow rate would exceed the maximum allowable flow rate of 200 mL/min.) The duplicate sample will take twice as long to collect.
    7.2. Extended duration samples should be collected by attaching a flow controller to each canister and then connecting the T-connector to each flow controller. (If only one flow controller was used, then the sampling duration would be twice as long.)

Bottle-Vac Sampling:

1. Measure the initial pressure with the digital pressure gauge. The initial pressure should be between -28 to -30 inches Hg. If it is less than -26 inches Hg, do not use the Bottle-Vac for sampling. If it is between -28 to -26 inches Hg, only use the Bottle-Vac if there are no other spares available. In the field log, record the Bottle-Vac ID, flow controller ID, initial vacuum, desired flow rate, sample location information, and all other information pertinent to the sampling effort.
2. For extended duration samples (for example, 8- or 24-hour)
    2.1. Remove the sampling manifold and attach the probe tubing to the flow controller.
    2.2. Attach the sign (identifying the canisters as an air sample, saying “Do Not Disturb” and providing contact information) to the canister.
    2.3. Make sure the canister will be secure at the sampling location; place traffic cones around the probe and canister if necessary.
3. For grab samples – Attach the flow controller to the sampling valve on the sampling manifold.
4. To begin sampling, attach the Bottle-Vac to the to the flow controller via the quick-connect and record the sample start time.
5. At the end of the sample period, detach the Bottle-Vac from the flow controller and record the sample end time. Detach the flow controller from the probe tubing or sampling manifold.
6. Measure the final Bottle-Vac pressure with the digital pressure gauge. The final pressure should be between -10 to -2 inches Hg. If it is 0 inch Hg, do not submit the sample for analysis. If it is between -2 and 0 inch Hg, redeploy the sample if possible; if not submit it to the laboratory for analysis but make sure it is received with some residual negative pressure.
7. Duplicate samples should be collected simultaneously with a dedicated T-connector as described in the Canister Sampling section.

Tedlar Bag Sampling:

1. Detach the vacuum pump from the sampling manifold and attach it to the lung box, then attach the probe tubing via the sampling manifold to the lung box influent.
2. Place a Tedlar bag in the lung box using dedicated Teflon and flexible silicon tubing.

3. To begin sampling, turn the pump on and record the sample start time.
4. Turn the pump off when the Tedlar bag is full and record the sample end time. The Tedlar bag should only be filled 50 percent if it will be shipped via plane.
5. Detach the probe tubing and vacuum pump from the lung box.

Sorbent Tube Sampling:

1. Disconnect the pump tubing from the manifold.
2. Attach a spare sorbent tube provided by the laboratory to the vacuum pump tubing using a 1/4-inch Swagelok union or flex tubing. Do not use a tube that is intended for sampling. Be sure to attach the sorbent tube so that the flow direction is correct.
3. Attach the SKC flow calibrator to the vacuum pump exhaust.
4. Turn on the vacuum pump and adjust the flow to achieve the desired flow rate of 200 mL/min using the flow calibrator.
5. Remove the spare sorbent tube from the pump tubing.
6. Remove the end caps from the sorbent tube to be used for sampling and attach it to the vacuum pump tubing using a 1/4-inch Swagelok union or flex tubing. Be sure to attach the sorbent tube so that the flow direction is correct. Record the sample tube ID on the field form.
7. Attach the other end of the sorbent tube to the sample manifold where the pump tubing used to be attached using either Swagelok fittings or flex tubing.
8. Make sure both the probe valve and the vacuum pump valve are open and the sampling valve is closed.
9. Start the pump and record the start time. Using flow calibrator, record initial flow rate.
10. If the flow rate starts to drop, it may indicate that the sorbent tube is becoming plugged with water. Stop the vacuum pump and record the end time.
11. After the required amount of time, record the final flow rate from the flow calibrator. Turn off the pump and remove the sorbent tube. Record the end time.
12. Replace the end caps on the sorbent tube. Replace the sorbent tube into the container it was received in.

After Sample Collection is Completed:

1. Disassemble the sampling system and replace the white silicone cap on the Vapor Pin.
2. For permanent probes - replace the black plastic or stainless steel secure cover and make sure it is securely in place.
3. Fill out all appropriate documentation (chain-of-custody and sample tags) and return samples and equipment to the laboratory in the same shipping container in which they were received. Do not place sticky labels or tape on surface of the canister.
4. Canisters, Bottle-Vacs, and Tedlar bags should not be cooled during shipment. DO NOT put ice in the shipping container. Sorbent tubes may require ice for shipping.

Quality Control and Quality Assurance

- Verify no less than 2 hours between probe installation and collecting subslab soil vapor samples.

- Canisters supplied by the laboratory must follow the performance criteria and quality assurance prescribed in U.S. Environmental Protection Agency (EPA) Method TO-14/15 for canister cleaning, certification of cleanliness, and leak checking.
- Flow controllers supplied by the laboratory must follow the performance criteria and quality assurance prescribed in EPA Method TO-14/15 for flow controller cleaning and adjustment.
- Field duplicates and trip blanks (sorbent tube methods only) may be required. Check the work plan for frequency.

Attachments

- Subslab Soil Vapor Sampling Log
- Sign identifying the canisters or Bottle-Vacs as an air sample, saying "Do Not Disturb" and providing contact information.

References

U.S. Environmental Protection Agency. Office of Solid Waste and Emergency Response. 2015. *Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air*. June.

Cox-Colvin & Associates, Inc. (Cox-Colvin). 2016. *Standard Operating Procedure – Installation and Extraction of the Vapor Pin*. September.

Subslab Soil Vapor Sampling Log

Project: ______

Sampler: ______

Sample Location Information

Property ID/Address: ______

Condition of slab in the surrounding area: ______

Location ID: ______ Sample ID: ______

Sample Location Description (Room Name/Number and surrounding, identifying features):

Subslab Soil Vapor Probe Leak Checking and Sampling Log

Manifold Leak Check

Manifold leak check (procedure: ensure manifold holds pressure at -10 "Hg for 30 seconds). If using a pelican-case pump, open the lid during leak check to ensure all interior pieces are in-tact.	*Pass*	*Fail*

Describe corrective measures taken to pass the manifold leak test: ______

Subslab Soil Vapor Probe Water Dam Leak Check and Purge Results

Purge rate (mL/Min): ______

Start Time: ______

Purge Vacuum ("Hg): ______

End Time:

Probe Leak Check Result*:	*Pass*	*Fail*

*The subslab soil vapor probe passes the water dam leak check if there are no bubbles observed and the water level does not draw down during purge. Do NOT collect a subslab soil vapor sample if the leak check fails.

Field Analysis (required readings are determined on a project-specific basis. Fill in all that are necessary):

MiniRAE or MultiRAE Photoionization Detector

Total VOCs (ppm): ______ O_2 (%): ______

H_2S (ppm): ______ LEL (%): ______

CO (ppm):

LandTec GEM Landfill Gas Meter

O2 (%): ______

CO2 (%): ______

CH4 (%):

Sampling Information

Evacuated Canister or Bottle-Vac

Container Size (L): ______ Initial Pressure (" Hg): ______

Container ID: ______ Start Date and Time: ______

Flow Controller ID: ______ End Date and Time: ______

Sampling Rate (mL/min, hours): ______ Final Pressure (" Hg): ______

Sampling Vacuum ("Hg):

Tedlar Bag

Tedlar Bag size (L): ______ Start Date and Time: ______

Sampling Rate (mL/min): End Date and Time:

Sorbent Tube

Sorbent Tube type and size: ______ Start Date and Time: ______

Sorbent Tube ID: ______ End Date and Time: ______

Initial Flow Rate (mL/min): ______ Final Flow Rate (mL/min) ______

Calculated Sampling Volume:

Weather Conditions and Additional Notes

Weather Conditions During Sampling: ______

Additional Notes: ______